MODERN ANÆSTHETIC PRACTICE

THE PRACTITIONER HANDBOOKS

Edited by SIR HUMPHRY ROLLESTON, Bt., G.C.V.O., K.C.B., M.D., F.R.C.P., and ALAN A. MONCRIEFF, M.D., F.R.C.P.

I. FAVOURITE PRESCRIPTIONS

II. PRACTICAL PROCEDURES

III. MODERN ANÆSTHETIC PRACTICE

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EDITORIAL PREFACE

Engineers and chemists have produced, in the last quarter of a century, the basis for great advances in the field of anæsthesia. A short symposium of articles on certain aspects of the subject was issued in *The Practitioner* recently and proved extremely popular. In response to repeated requests it has been decided to expand this symposium into a practical manual of anæsthetics suitable for the general practitioner in his every-day work. To this end the authors of the contributions already published (Drs. Blomfield, Ashworth, Elam, Evans, Vaile, and Hasler) have revised their original articles, and, in addition, completely new accounts of important aspects of anæsthesia are included. The authors of these new contributions, Drs. Hewer, Featherstone, Challis, Prof. R. R. Macintosh, Mrs. Freda Pratt and Mr. Romanis, have paid special attention to the problems of the general practitioner. A valuable contribution by Dr. Magill on post-operative aspects of anæsthesia, which originally appeared in a special symposium on post-operative conditions, has been included, and Dr. Hasler has written a new article on spinal anæsthesia in addition to his interesting contribution on anæsthetic explosion risks.

As Dr. Blomfield points out in his introduction, the increased complication and mechanization of the anæsthetist's occupation is the most striking feature of anæsthetic practice to-day. Yet the fundamental principles remain, as Dr. Langton Hewer points out, and practitioners will do well to study his valuable survey of those theoretical aspects of anæsthesia and analgesia which must remain the basis of all their practical work. The choice of anæsthetics depends partly upon the particular

purpose for which relief of pain is desired, partly upon the patient's own feelings in the matter, and partly upon the practitioner's own skill and experience. The bulk of this book provides for all these possibilities. Anæsthesia is no longer a "rag and bottle" affair! Science has made great advances possible and these advances are here interpreted for the benefit of those who wish to master one branch of medicine in which the general practitioner is still rightly expected to be a skilful and kindly exponent. The editors desire to extend their cordial thanks to all the contributors who have so carefully set out their expert experience in a thoroughly practical form.

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INTRODUCTION

By J. BLOMFIELD, O.B.E., M.D.

INTRODUCTION

WHEN the practice of anæsthetics thirty, twenty, or even ten years ago is compared with the procedures common in that department of medicine to-day the first thing that strikes the observer is the increased complication and mechanization of the anæsthetists' occupation. In themselves these changes cannot be considered desirable evidences of progress, but the advantages which they bring outweigh their own essential defects. Obviously the more simple any practical procedure can be kept the better, for it will be more easily learnt and will give scope for fewer mistakes than the more complex process. The practice of the anæsthetist was simple enough in former days and has been contemptuously described as a "rag and bottle" administration. At its most elaborate it required nothing more than a Clover's inhaler and a gas machine of the old type. Nowadays the Clover has almost completely disappeared—not some think for sufficient reason—the drop bottle and mask are relegated to country districts, and the gas machine has become a complicated contrivance which is capable of delivering cyclopropane or ethylene and carbon dioxide in addition to its ordinary task of supplying nitrous oxide and oxygen with supplemental ether if required. In fact the anæsthetist to-day must have as good a working knowledge of pressure-gauges, flow-meters, valves, stopcocks, and

manometers of all kinds as he must have of the respiratory and circulatory systems of his patient. Indeed the latter are more often kept under observation by the use of dials and scales and bags than by directly noticing the colour, pulse, and breathing of the patient. Very often none of these are visible or palpable during operation. The machine has to be more observed than the patient, and it is on the first rather than on the second that the administrator relies for guidance. He notices more what his machine is doing than what effect it is having. Yet machines are not infallible and do not always do what they say they are doing. Flow-meters, for example, are never absolutely accurate, yet their readings are acted on with simple trust.

DANGERS OF MODERN METHODS

The advantages which accrue from complicated apparatus are not obtained without their price. Those advantages will be stated later: it is proposed first to glance at the price paid for them.

First there are the accidents which arise so much more easily when the apparatus in use is complex than when it is simple. Under this heading must be placed disasters following wrong fitting up of the machine, so that, for example, carbon dioxide is given by mistake for oxygen, or liquid anæsthetic is delivered into the air passages. Explosions due to faulty electric connexions or to static sparks generated near or on the machine are another class of accident unknown in simpler times, and the passage of the tube conveying the anæsthetic into the alimentary instead of into the respiratory tract comes into the same category. Of course it may be said that most of these accidents are preventable by care, but human beings are

not infallible nor machines fool-proof.

A second disadvantage to be laid to the account of complicated apparatus relates to the teaching of anæsthetics. It is difficult nowadays for the teacher in hospital to instruct the student in those methods which alone will be available for him when he goes out into practice. The average practitioner will not care to spend considerable sums of money on apparatus which he will rarely use, if indeed he is skilled in its use at all. Yet it is with just such apparatus that most of the anæsthetics have to be given which are in the hands of the specialist at a hospital and which the student watches for instruction. Naturally the specialist must do what is best for the patient and for the operator with whom he is working Most of the work on which they are engaged together in hospital is of a nature which does not allow the anæsthetic to be handed over to a student, or to be conducted by the simple measures available to the man who is not practising anæsthetics as a specialty. The trend of practice is to put anæsthetics more and more into the hands of specialists, and ideally every anæsthetic should be given by a man who has had special training to that end. This ideal requires the training of a far greater number of specialists than is at present possible from an economic point of view. In the meantime, though anæsthetics in hospital fall more and more completely into the hands of those specially trained, it is inevitable that outside hospitals many must be given by men who are deprived of adequate training by the present arrangement of affairs and go out into practice less competent to give an anæsthetic than preceding generations who did at least have some practice in the simple methods of their time.

CAUSES OF PRESENT-DAY TRENDS

The complication of anæsthetic apparatus and methods has

arisen mainly from two causes. These are the employment of gaseous anæsthetics instead of those which are liquid in their natural state, and the use of basal narcosis. To these must be added the method of endotracheal anæsthesia. The old anæsthetics, ether and chloroform, are poisons. Every anæsthetist knew this and his efforts were directed to securing the utmost anæsthetic influence of the drugs while diminishing, so far as lay within his power, their toxic effects. The trend of practice to-day is to banish ether and chloroform entirely from the anæsthetic field. So far as ether is concerned the toxic effects were seldom obvious at the operation itself, but many fatalities in the post-operative period could in all probability be justly laid to the account of prolonged ether inhalation. Professor Finsterer has demonstrated the truth of this as far as operations on the upper abdomen are concerned. Chloroform was doubly guilty, for it could, and did, cause sudden death early in its inhalation as well as by overdose, and it caused later fatalities through its damaging action on the parenchyma of liver, kidneys, and heart.

The anæsthetist sought, and for long sought in vain, for an anæsthetic which could produce satisfactory anæsthesia and relaxation, but without toxic effects. Abroad, the problem was most often solved by prosecuting the study of local anæsthetics. This way out has never made the same appeal to British and American operators, partly because many patients are intolerant of merely local analgesia, partly because of the amount of time and trouble demanded of the surgeon, and partly because in America and Great Britain there have always been a number of men devoting themselves to the practice of anæsthetics in a way which did not hold good on the continent. It is interesting to observe that this difference in practice is diminishing not through greater use of local methods here

and in America but through a greatly increased interest in general anæsthesia on the continent. This interest is shown by the recent production in Germany, France, and Italy of journals solely concerned with the practice of anæsthetics. Moreover there are now to be found in those countries men who, as has long been true here, practice mainly if not solely as anæsthetists.

The need for a non-toxic anæsthetic was but partially met by nitrous oxide so long as this sufficed only for operations which were short and which did not require full muscular relaxation. It was the invention of apparatus which enabled the gas to be given for long periods of time continuously with oxygen and enabled it to be given under pressure that brought nitrous oxide into the field as an efficient substitute for ether and chloroform in major surgery. When the machines were so contrived as to permit the addition to the gases of ether vapour if necessary, then they were efficient even for the exacting requirements of the surgeon at work on the upper abdomen. Nowadays the apparatus for prolonged administration of nitrous oxide generally caters also for the admission of ether, cyclopropane or vinesthene, and carbon dioxide, as well as oxygen. Another way, besides the addition of ether, in which it was found possible to enable nitrous oxide to cope with the needs of severe operations was by premedication or, as it is called in its extreme form, basal narcosis.

PREMEDICATION

Those who relied on "gas and oxygen" found that if they gave heavy doses beforehand of morphine and scopolamine then their gases sufficed for operations for which they were insufficient without this aid. The introduction of avertin from

Germany and of the barbiturates from America has greatly extended the use of basal narcosis. One more complication is thus added to the anæsthetist's procedure, but it entails enormous advantages. With the aid of these strong sedatives or hypnotics the gases nitrous oxide, cyclopropane, and ethylene, themselves infinitely less toxic than ether and chloroform, are able to replace those drugs often if not always. It is easy to understand the wide popularity which has greeted the introduction of premedication as a routine part of anæsthetic practice. Even the most timorous or highly-strung patient is relieved of her dread when she understands that she will be asked to endure nothing more formidable than an injection made per rectum through a small soft tube, or a prick of the skin, or the swallowing of a tablet or two, and whichever method is adopted it will be employed on her while she is still in bed and afterwards she will know nothing more of her operation till she wakes up again back in her bed. Objection has been raised against premedication that it gives the patient's system more drugs to cope with, and that it prolongs dangerously the period of unconsciousness after operation. The answer is that, like many other processes, basal narcosis has the defects of its good qualities, but that the former are not seen if the process is properly and judiciously employed. Each patient has to be seen beforehand and the most appropriate form of premedication decided on, as well as its exact dosage.

ENDOTRACHEAL ROUTE

Many attempts have been made to widen the scope of local analgesic methods by combining them with premedication, and the practice is often successful. In one department of surgery in which it was naturally expected to be of the greatest

service it has proved disappointing; this is in the prolonged operations now usual in the treatment of cerebral tumours. Here a great deal of the operation is carried out on tissues of slight or no sensibility and a general anæsthetic to abolish pain is uncalled for. Unfortunately if only local analgesics were used after basal narcosis it was found that the effects of both wore off before the operation was finished and a restless condition which the patient could not control was apt to appear. This leads to administration of a general anæsthetic on the table; this is most undesirable from the general upset which it causes, and particularly because it encourages bleeding, the surgeon's chief obstacle at these operations. Local analgesics alone are unsatisfactory because the patient cannot endure the prolonged restriction in one position even if no pain is felt. Modern cerebral surgery demands complete control from first to last of the patient's respiratory and circulatory systems and it is found that this is impossible unless the patient is kept unconscious throughout. Moreover, since the degree of anæsthesia required is for most of the time only a light one, this prolonged narcosis does not add materially to the risks of the operation It is commonly secured by the continuous administration of nitrous oxide and oxygen endotracheally. The endotracheal method renders the posture of the patient of no importance so far as the introduction of the anæsthetic is concerned and its advantages are nowhere better displayed than during operations for cerebellar growths on patients who are necessarily prone. The introduction of this method, the endotracheal, has altered the anæsthetist's practice more perhaps than any other innovation of recent years. Many of the troubles which once hampered smooth anæsthesia and the avoidance or overcoming of which were almost the chief concern of the anæsthetist were due to swelling or spasm of the tongue and the

walls of the upper air-passages. The endotracheal method completely avoids this whole class of inconvenience, and also renders easy the safeguarding of the air-passages during operations which involve the risk of their being invaded by blood or other foreign body. For some grave intrathoracic operations the method is essential and it has been justly claimed that the great advance in this branch of surgery has been rendered possible only by the aid of endotracheal anæsthetics. Here again the method has its own risks and in unskilled hands the larynx may be damaged, or the œsophagus invaded by mistake.

ADVANTAGES OF MODERN METHODS

Attention has been directed to the defects of present methods and reference made to *their* advantages, but these may now be briefly summarized. First the toxic anæsthetics are needed to a much smaller extent, if at all. This diminishes operative risks, lessens post-operative complications, and greatly improves the immediate post-operative condition of the patient. Secondly, basal narcosis saves the patient from all that danger which is associated with the psychical side of anæsthesia and is formidable, for example, in the subjects of exophthalmic goitre. For the ordinary patient it removes the idea of operation and robs anæsthesia of dread. Thirdly, endotracheal methods obviate many of the troubles hitherto associated with the taking of an anæsthetic and also facilitate many operations, as well as rendering some possible which could not be performed without their aid.

Hitherto no mention has been made of spinal analgesia, a method which in its proper place is invaluable and gives results not to be equalled otherwise. There is still, however, much difference of opinion about the merit of various details in

procedure, and some authorities remain convinced of the adequacy of the original method. Lately there has been a considerable move, started by Gogliotti, towards an analgesia produced by injection that affects the spinal roots without entering the cerebrospinal space. Lastly, mention must be made of the excellent results that are obtained by combining local with general methods during the performance of severe abdominal operations. Splanchnic analgesia for the upper, and spinal for the lower abdomen have, in conjunction with gas and oxygen and sometimes avertin, allowed the patients subjected to gastrectomies and excisions of the rectum to recover in a way impossible after long inhalations of ether or chloroform. It may well be that increasing use of local analgesics supported by non-toxic general anæsthetics will distinguish the next advance in anæsthetic methods. Electric anæsthesia which has given excellent results in veterinary surgery has not yet been seriously applied to human beings.

CHAPTER 1

THEORETICAL ASPECTS OF ANÆSTHESIA AND ANALGESIA

By C LANGTON HEWER, M B , B S , D A

CHAPTER I

THEORETICAL ASPECTS OF ANÆSTHESIA AND ANALGESIA

IN order to produce general anæsthesia, it is necessary temporarily to suspend the functions of the cells of the cerebral cortex by means which will not affect their vitality nor that of any other cells of the body. The various methods, which are available for this purpose are psychical, physical, and chemical.

HYPNOSIS

The theory of hypnosis is simple. It has been shown that the cortical grey matter can be divided into three layers: (1) the supragranular layer which can be taken to comprise the conscious brain and is governed by such laws as those of reason and argument; (2) the granular layer which deals with subconscious memory; and (3) the infragranular or "instinctive" layer. The two lower layers together constitute the subconscious brain and obey the laws of reflex action. If interference from the top or supragranular layer can be prevented by psychical means, the subconscious brain will blindly accept any suggestion made to it such as insensibility to pain. Although suitable subjects can be rendered anæsthetic by hypnosis alone and many operations have been performed with this method in the past, conditions are too variable to make success

reasonably probable and pure hypnotic anæsthesia has now been abandoned. At the same time, anæsthetists can and do make use of suggestion before and during the induction of narcosis with marked benefit.

ELECTRICITY

Of the various physical methods of producing anæsthesia, electricity is probably the most interesting theoretically and the most disappointing in practice. It has been known for many years that during general anæsthesia the cerebral cortex becomes electro-positive and it was suggested that the muscular movements of the second stage were due to electro-negative charges (or nerve impulses) leaving the brain via the motor nerves. It was reasonable to suppose that the converse was true and that anæsthesia could be produced by electric currents. This seems to be the case in some animals. For example, if a 2 milliampère direct current of 110 volts is passed through the water in which a gold fish is swimming, the animal becomes perfectly motionless and apparently deeply anæsthetized with its head resting against the positive electrode. In man, however, attempts to produce anæsthesia by means of electricity have frequently resulted in a "nightmare state," the patient being paralyzed and apparently insensitive but actually he may retain consciousness and sensation. At the present time, therefore, electricity can be ruled out as impracticable.

VOLATILE ANÆSTHETICS

The volatile or inhalation anæsthetics can be considered together although they act partly by chemical and partly by physical means.

The following compounds are gases at ordinary temperatures and pressures :—

NITROUS OXIDE	N_2O
ETHYLENE	C_2H_4
ACETYLENE	C_2H_2
CYCLOPROPANE	C_3H_6
ETHYL CHLORIDE	C_2H_5Cl

the vapours of the following liquids are also used :—

DI-VINYL ETHER	$[C_2H_3]_2O$
DI-ETHYL ETHER	$[C_2H_5]_2O$
CHLOROFORM	$CHCl_3$

The above order is important for reasons which will be explained.

Absorption, effect on respiration and elimination.—Volatile anæsthetic agents enter the blood stream from the pulmonary alveolar epithelium and this process will continue until the tension of gas in the blood equals the partial pressure in the alveoli. When the administration is discontinued, the mechanism is reversed and the gas will be eliminated via the expired air. It therefore follows that the depth of anæsthesia can be regulated with rapidity and precision provided that respiration is taking place. It is possible to introduce a volatile anæsthetic by means other than inhalation, e.g. di-ethyl ether can be given (in saline) intravenously and (in oil) by the rectum. In either event most of the drug will be eliminated by the lungs. If an open inhalation technique be adopted it is obvious that much waste of the agent will occur from diffusion into the air. If, however, the patient is made to rebreathe completely, the amount of added drug can be reduced to negligible proportions when once anæsthesia has become established and a state of equilibrium attained. The atmosphere within the closed circuit is rendered constant by the absorption of carbon dioxide (usually by means of soda-lime) and the addition of oxygen sufficient for the patient's basal metabolic rate (called

the "basal flow"). Further advantages of the closed technique are the reduction of heat and fluid loss by respiration. The volatile anæsthetics are eliminated to a very small extent through the skin, but this is of no practical importance. All narcotic drugs depress respiration if pushed to the stage of overdosage, but some (e.g. di-ethyl ether) cause stimulation in the lighter planes of anæsthesia. The depth of respiration depends upon three main factors:—(1) the stimulating or depressant action of the anæsthetic employed; (2) the percentage of carbon dioxide in the alveolar atmosphere; and (3) the degree of surgical stimulation.

Certain of the volatile anæsthetics cause irritation of the upper air-passages with excessive secretion. High concentrations of di-ethyl ether are particularly liable to cause this effect and consequently the pre-operative administration of atropine or scopolamine is usually adopted before using this drug.

Effects on the blood—Inhalation anæsthesia produces various blood changes. The agents themselves do not apparently form any definite combination with hæmoglobin but "dissolve" in the corpuscles and plasma. Leucocytosis, hæmolysis, prolongation of the coagulation time and an increase in the blood cholesterol have all been observed during anæsthesia. As a rule these changes are negligible at the nitrous oxide end of the scale and are most pronounced with chloroform.

Effects on the central nervous system.—If a drug is to be useful as a general anæsthetic, it is necessary that it should act on the more specialized parts of the central nervous system such as the cerebral cortex, before affecting the vital centres. Fortunately many agents have this property and the way in which they act has been the subject of much controversy.

It is known that the cortical cells use oxygen at a higher rate than other cells and it is probable that all general anæsthetics

curtail this process. The lipoid-soluble drugs, such as chloroform and ether, probably enter into chemical combination with the lipoids of the cell membranes and cause a reversible coagulation of the cell protein. In other words, the cortical cells are temporarily poisoned and are unable to use oxygen. Nitrous oxide, on the other hand, probably has no chemical action at all but simply limits the oxygen supply to the cerebral cells by displacement of oxygen in the body fluids—a purely physical process. The other anæsthetics can be regarded as acting partly in one way and partly in the other, their order of toxicity being that given at the beginning of this section. It should be noted that if the cortex is very active (as in excited patients) a higher concentration of anæsthetic will be necessary in order to inhibit function. The value of pre-operative sedative can therefore be clearly seen.

Traumatic stimulation may be a factor in the production of shock although the stimuli will not be perceived by a patient under general anæsthesia since the cortical functions are in abeyance. The deeper the narcosis, the less is this effect seen. The subject of "reflex shock" will be referred to again when considering local analgesia. It should be noticed that the more toxic drugs produce more profound narcosis and the aim of the modern anæsthetist is to provide adequate muscular relaxation for the operation required by means of the least toxic drug or combination of drugs.

Ketosis.—All volatile anæsthetics with the possible exception of nitrous oxide diminish the alkali reserve of the blood and tend to produce ketosis, the most obvious result of which is "anæsthetic vomiting." The pre-operative administration of sodium bicarbonate was thought to minimize this condition but better results are obtained by giving glucose or sodium lactate. The blood-sugar value is raised after anæsthesia and

this is due to mobilization of glycogen from the liver. The post-operative administration of small doses of insulin enables the tissues to utilize the sugar and generally restores the level to normal within a short time. Insulin is also of great service in anæsthetizing diabetics as it lessens the anæsthetic risk to that of normal patients.

Effects on the liver.—Impairment of liver function can now be measured extremely accurately by means of a dye-retention test. Bromsulphthalein is injected intravenously and the liver should be able to remove it completely from the blood within a given time. It has been found that nitrous oxide, ethylene and cyclopropane produce no impairment of liver function in the presence of adequate oxygen. It is possible for ethyl chloride, di-vinyl ether and di-ethyl ether to cause recognizable delay in dye removal, whilst chloroform can produce grave and prolonged changes. In extreme cases the acute yellow atrophy of "delayed chloroform poisoning" may ensue. It has been shown that liver cells laden with glycogen are more resistant to toxic narcotics, and this constitutes a further argument for the pre-operative administration of glucose or sodium lactate. It has also been demonstrated that the administration of excess oxygen with a normally toxic volatile anæsthetic minimizes liver damage, while conversely, anoxia increases it. Jaundiced patients should be given calcium in the pre-operative period. This not only shortens the coagulation time of the blood but protects the tissues from the toxic effects of bilirubin and abnormal liver products such as methyl guanidine.

Effects on the heart.—The volatile anæsthetics may affect the neuromuscular mechanism of the heart producing primary cardiac failure. Chloroform is the usual cause of this and failure may be due either to vagal stimulation or ventricular fibrilla-

tion. These tragedies nearly always occur during light anæsthesia and provide an overwhelming bias against the practice of using the drug as a routine agent in the induction period. It is possible that a full dose of atropine given before operation may afford some protection against vagal stimulation and it is established that an excess of adrenaline in the circulation (either added artificially or from the patient's own glands) predisposes to ventricular fibrillation.

All the inhalation anæsthetics can produce secondary cardiac failure in gross overdosage. This is due both to the toxic effect of the drugs on the myocardium and also to the accompanying anoxæmia.

Changes in pulse rate and rhythm are commonest with cyclopropane. Bradycardia, tachycardia, and arrhythmia are all seen in overdosage. Electrocardiagraphic tracings do not show important changes except in the case of chloroform when a "pre-fibrillation phase" can sometimes be demonstrated just before full surgical anæsthesia is reached.

Effect on the kidneys and urine.—Nitrous oxide apparently has no effect on the kidneys but prolonged anæsthesia with all the other agents reduces the urinary output and may be followed by transient albuminuria which is probably due to slight toxic changes in the renal cells. *Acetonuria is common and the blood* urea usually shows a moderate rise.

OTHER GASES USED IN ANÆSTHESIA

Two other gases are sometimes used in conjunction with inhalation anæsthesia, viz. carbon dioxide and helium.

Carbon dioxide.—Man normally breathes air containing about 0·04 per cent. carbon dioxide. If this proportion is much higher it will cause an immediate increase in the depth of respiration. "Partial rebreathing" occasions such an increase and tends to offset the respiratory depression caused by

anæsthetic drugs. Carbon dioxide (up to 7 per cent.) may be added from cylinders to the inspired atmosphere after operations in order to eliminate volatile anæsthetics quickly from the lungs and to expand the pulmonary bases. It may also be used immediately before intubation in order to widen the glottic opening. The other chief uses of carbon dioxide are in the treatment of respiratory depression from overdosage of volatile and other narcotic drugs, in asphyxia neonatorum and in persistent hiccough.

Helium.—Helium is, with the exception of hydrogen, the lightest gas known, having a density of 0·138. Thus helium will "thin" or lower the density of inhaled gases and it has been shown that the resulting mixture can be breathed through a constricted aperture in greater volume and with less effort by the patient. Thus helium may be of great temporary value in respiratory obstruction before the airway can be cleared. For example, it may be possible to anæsthetize a patient suffocating from an intrathoracic tumour with a mixture of cyclopropane–helium–oxygen until such time as the surgeon has removed the respiratory obstruction. The gas is also useful in intrabronchial anæsthesia.

NON-VOLATILE NARCOTICS

The non-volatile narcotics used in anæsthesia can be classified as follows:—

PARALDEHYDE
AVERTIN

BARBITURATES
- long-acting, used as basal narcotics.
  - SODIUM AMYTAL
  - NEMBUTAL
  - PERNOCTON
  - SODIUM SOMERYL
  - HEBARAL SODIUM
- short-acting, used as basal narcotics immediately before operation or as intravenous anæsthetics.
  - EVIPAN SODIUM
  - PENTOTHAL SODIUM
  - EUNARCON
  - NARCONUMAL

The number of barbituric acid derivatives is so large that only those in common use have been mentioned. The terms "long" and "short-acting" are relative since certain members not used extensively in anæsthesia have a much more prolonged effect.

Administration—Paraldehyde and avertin are usually given in diluted form by the rectum while the barbiturates can be administered by the mouth, rectum or vein for basal narcosis but are always given intravenously for full anæsthesia. Most of the series are unstable in solution and must be freshly prepared for intravenous work but exceptions are pernocton and eunarcon, which are obtainable in liquid form in ampoules

Elimination—The chief difference between the volatile and non-volatile narcotics is that the latter are not eliminated to any appreciable extent by the lungs but are "detoxicated" by the liver and finally excreted by the kidneys. It therefore follows that control of narcosis is less certain and accurate whilst the patient's hepatic and renal functions must be reasonably good. It is true that paraldehyde is partly excreted by the lungs, a fact upon which ward sisters frequently comment! Since pentothal sodium contains sulphur it should not be given to patients receiving sulphanilamide preparations Toxic jaundice has occasionally been observed after the use of non-volatile narcoties.

Effects.—Besides loss of consciousness, the most obvious effects of this group of drugs are a fall in blood pressure and depression of respiration. Paraldehyde shows these changes least. With regard to the barbiturates, the members of the series which are eliminated slowly cannot be used for complete anæsthesia because respiratory and circulatory depression become excessive in the necessary doses. Most of the effects discussed under the volatile drugs may also be seen.

Overdosage in treated by artificial respiration with CO_2 and O_2 mixture, and the intravenous injection of analeptics such as coramine and picrotoxin. Lumbar puncture with drainage of cerebrospinal fluid is said to be beneficial in barbiturate poisoning.

LOCAL ANALGESIA

Most of the drugs used in local analgesia are lipoid-soluble alkaloids. The non-irritating water-soluble salts of these alkaloids are employed for injection. The slight alkalinity of the tissue fluids is believed to hydrolyze the salts and the resulting alkaloidal bases are taken up by the lipoids in the adjacent nerve tissue. Another factor is probably the ionization of the alkaloidal salt which produces an ion of the corresponding base having a positive charge. This is taken up by a nerve structure carrying a negative electrical charge. Whatever be the exact mechanism, the effect produced is complete depression without preliminary stimulation. The depression, however, is not uniform. For example, in mixed nerves the sensory fibres are affected before motor ones, while the order for loss of function is first vaso-constriction, then temperature, pain, touch and lastly joint and pressure sensation. In animals this order corresponds with the thickness of the myelin sheath of the various fibres. Since the passage of traumatic stimuli to the brain is interrupted in local analgesia, "reflex" shock is practically abolished but it should be noted that since the cortex is still functioning, "psychic" shock may occur. Crile recognized the importance of combining the two methods many years ago when elaborating his "anoci-association" technique.

DRUGS EMPLOYED

The drugs used in local analgesia can be divided into cocaine and its derivatives and quinine derivatives.

Cocaine was the original drug introduced in 1884 and is the only local analgesia known with a vasoconstrictive effect. Its toxicity is, however, so high that at the present time it is only used for surface or "permeation" analgesia.

Cocaine derivatives. Novocain (also known by eight synonyms) was brought foward in 1905 as a cocaine substitute and is still widely used for infiltration and for field or nerve-blocking. The toxicity of novocain is low but its full effect rarely lasts for more than an hour. Owing to the fact that this drug and other cocaine substitutes have a vaso-dilator effect, it is customary to incorporate adrenaline (in a final dilution of about 1 in 400,000) or some other vaso-constrictor in the injected fluid Novocain has a poor surface action.

If a more prolonged analgesia is required *pantocain* (syn *decicain*) is often used. It appears to be rather more toxic than novocain but has a much more pronounced surface effect.

A very large number of other cocaine derivatives have been and are being tried.

Quinine derivatives. Quinine and urea hydrochloride was introduced in 1904 and has a very prolonged action as has *quinine hydrochloride and urethane* ("cucupin"). *Percaine*, discovered by Meischer in 1929 is an extremely potent and long acting drug and has an excellent surface action It has produced a revolution in the technique of spinal block.

Some of the above mentioned solutions are themselves bactericidal while others have sufficient antiseptic added to render sterilization unnecessary. In either event, however, it should be noted that such solutions form no exception to the rule that injections must not be made through inflamed or septic tissues.

GENERAL TOXICITY

All local analgesics are protoplasmic poisons having a special affinity for nerve tissue and if a sufficient quantity

reaches the circulation at one time, the vital medullary centres will naturally be affected. Cases of collapse can be divided into three main groups.

Overdosage.—An overdose of a toxic drug such as cocaine may readily occur if the injection method is employed, but the safety margin is fairly high with most of the other drugs. It should be remembered that the potency of such agents is in direct ratio to their concentration, whereas their toxicity is in geometrical ratio to the concentration. The barbiturates have been shown to raise the minimal lethal dose of cocaine and its derivatives, a fact to keep in mind when deciding upon a basal narcotic. The symptoms of overdosage are usually excitement, restlessness, dilated pupils, feeble and rapid pulse, while in severe cases convulsions may precede unconsciousness and death.

Idiosyncracy.—This unsatisfactory term is the only reasonable explanation of collapse and death following the injection or mere surface application of trifling amounts of local analgesics. It is possible that psychic shock may play some part in these fatalities, and an allergic factor may sometimes be present since fatalities have occurred in cocainizing the nose in asthmatic patients.

Inadvertent intravenous injection.—Since the intravenous lethal dose of local analgesics is about one-tenth that of the subcutaneous lethal dose, it is obvious that great care must be taken to avoid puncturing a vein. During infiltration and field-blocking, the needle point must be kept constantly on the move, while, if a large volume of solution is to be injected into one area, as in nerve-blocking, the aspiration test must always be negative.

LOCAL TOXICITY

Sterile isotonic solutions of most local analgesics should set

up very little tissue irritation. It is, however, essential that the adrenaline content should not be excessive since it has been shown that a concentration of 1 in 20,000 can readily produce necrosis whilst considerably weaker solutions can cause trouble in patients suffering from vasomotor and trophic disturbances. The dangers of injecting through infected areas have already been mentioned. The golden rule in local analgesia is to use the smallest quantity of the weakest solution of the least toxic drug which will produce the required effect. Permanent damage to nerve structures occasionally follows nerve-blocking and is, of course, aimed at in such procedures as injection of the Gasserian ganglion with alcohol for trigeminal neuralgia. Spinal analgesia, which can be regarded as a multiple nerve-block, may be followed by symptoms indicative of damage to the cauda equina.

CHAPTER II

THE USE OF VOLATILE ANÆSTHETICS

By H. W. FEATHERSTONE, M.D., D.A.

CHAPTER II

THE USE OF VOLATILE ANÆSTHETICS

IN former days, when the manufacture and the handling of gases were little understood, it was perhaps natural that the investigators who sought to find an efficient medium for producing unconsciousness, or at least *insensitiveness* to pain, looked for a substance which was liquid under normal conditions but which would give off a vapour that could be inhaled by the patient in a convenient manner. Moreover, it was apparent that the inhalation portal of entry for such drugs, which clearly had to be administered in large doses in order to produce their full pharmacological effects, presented the essential advantage that the dosage could be controlled to a nicety, because excess of the drug could be speedily withdrawn by exhalation. Therefore the "trial and error" method of investigation was far safer when using inhalational narcotics upon human beings than if potent solid or liquid substances were inserted irrecoverably into the body either by the mouth, the rectum, or the blood stream.

These advantages are still appreciated by anæsthetists, and the employment of ether, chloroform, and ethyl chloride in anæsthesia is the usual practice of nearly all practitioners who give anæsthetics occasionally, and also of many anæsthetists when they are working away from the main operating clinics.

Furthermore, these drugs are inexpensive, they may be stored for a long time without deterioration, administration is not difficult, apparatus is simple and durable, and ether and chloroform are powerful anæsthetics which are suitable for the requirements of nearly all major operative procedures.

ETHYL CHLORIDE

Stored in stout glass tubes under slight pressure this agent retains the liquid state but on exposure to the air of the room it evaporates. The odour of the gas is somewhat disagreeable but is conveniently masked with eau-de-cologne, and the olfactory sense is lost after one or two breaths. It is rapidly absorbed and excreted, powerful in low concentration, and produces deep anæsthesia speedily, the excitement stage usually being unnoticed. Overdose is not a serious danger, for by rapid excretion a high concentration in the blood can be speedily reduced. However, possibly on account of its halogen atom, ethyl chloride may harm the heart muscle and the liver parenchyma, and as a sign of this tendency patients may complain of headache and nausea after quite short administrations. Few anæsthetists nowadays employ ethyl chloride for prolonged anæsthesia. It is convenient for a short single-dose administration and also for inducing anæsthesia which is afterwards maintained with ether.

The single dose method is specially useful in children's clinics for the removal of teeth or the enucleation of tonsils by the guillotine. The pleasant and quick induction suits the child, the profound relaxation helps the operator, and the speedy recovery soon restores the protective cough reflexes. Moreover, the free oxygenation of the blood which is ensured may be contrasted with the tendency to cyanosis which accom-

panies the administration of nitrous oxide for surgical measures upon small children whose air passages are immature and narrow.

When using ethyl chloride for induction, in an anæsthetic sequence, it is necessary to instil the succeeding drug as rapidly as possible in order that the patient may be under the full effects of the second narcotic before the evanescent effects of the ethyl chloride have passed off. For this reason it is dangerous to follow ethyl chloride with chloroform; ether is nearly always used to continue and maintain anæsthesia.

The "closed" or the "open" methods may be employed When using the "closed" method for a single dose administration, 3 to 5 c.cm. of the drug should be sprayed into the bag the dose varying with the size and physique of the patient, and the bag having been applied during a full expiration, air leaks round the facepiece should be avoided. As soon as automatic breathing has been established the apparatus should be removed, for with speedy induction it is usual to find that anæsthesia continues to deepen for some seconds after the administration has been stopped. If the drug is given on an open gauze mask, more ethyl chloride is required, for it is administered by the drop method, and both induction and recovery are more prolonged than with the "closed" technique.

Ether may be added in the "closed" method either by using a sponge, as in the Ormsby bag, or in a tank, as in the various forms of Clover's inhaler. With the open gauze mask the ether is added according to the suggestions which will be included in the section on the use of ether.

ETHER

Ether boils at 35° C. but volatilizes at much lower temperatures. Nevertheless in a cold room or when the gauze mask has

been chilled by the rapid evaporation of a large quantity of ether, it may be difficult to obtain a free supply of vapour. Furthermore the cold vapour produced by breathing through a chilled mask is actually a fog of ether droplets, which is particularly irritating to the epithelium of the respiratory passages. The blood on its way through the lungs is cooled, and in view of the fact that about one-fifth of the heat loss from the body in a cold atmosphere occurs from the lungs the prolonged administration of chilled and incompletely vapourized ether is harmful.

Successful ether anæsthesia therefore depends largely upon the administration of well-vapourized ether gas, and this has been effected in Shipway's well-known apparatus by blowing ether vapour and air through a metal U-tube dipped in hot water in a thermos flask. The gaseous mixture is taken to the patient through a rubber tube which ends under a gauze mask, or more usually, is joined to a rubber catheter placed in the inferior nasal meatus, or in an oral airway, so that the ether gas is delivered into the pharynx. This method gives smooth anæsthesia, provided the air is pumped with sufficient force and the temperature in the ether bottle is well above freezing point. Deep surgical anæsthesia can rarely be obtained unless wide tubing, rapid evaporation (by surrounding the ether bottle with hot water), and a good flow of air are provided.

Other methods for producing warm ether gas are King's Thermanester, and Pinson's Ether Bomb. The former apparatus requires that the patient lie on the back with his face pointing directly upwards. Ether from a tank in the upper part of the machine, which is placed on the face with a close-fitting mask, drips at regulated frequency on to cotton wool in a chamber which is surrounded by a hot water tank. Warm

air is drawn by the patient round the hot water tank thus causing complete "gasification" of the drops of ether, and the ether-air gas mixture is then drawn through an inspiratory valve into the face piece and thence to the air passages. Exhaled air escapes through a separate expiratory valve and there is no rebreathing. Pinson's Bomb is a strong steel container which is charged with ether, but not completely filled. It is then placed in a dish of boiling water and the ether boils to form gas at a pressure of about 98 lb. to the square inch By means of a needle valve and fine stout-walled rubber tubing the pure gas is conducted to a gauze mask under which it is delivered to the patient. Alternatively the ether gas may be taken directly to the pharynx. When using the apparatus care must be taken to avoid overdose. Some anæsthetists consider that heating ether in this manner may lead to the formation of injurious impurities.

When employing the usual per-balational method of evaporating ether on a mask, such as the Schimmelbusch or Yankauer, covered with gauze, certain points should be observed A thickness of about 30 to 40 layers of gauze should be placed on the mask; by using a thick pile of gauze, not only is the respired air from the patient mixed with the evaporating ether and then to some extent rebreathed by the patient, but all air *entering the patient's air passages has been passed through* the ether-laden material. The ether should be poured on to one part only of the gauze, the highest part of the pile, so that it sinks into the deeper portions of the gauze before evaporating. If on the other hand the ether is poured all over tbe outside of the gauze pile much is lost by evaporation into the outside air, and furthermore the whole pile is chilled by the rapid evaporation. The method of internal evaporation conserves the heat of the respired air in the mask, reduces the loss of ether,

and prevents the formation of ether fog. The edges of the gauze which lie on the face should be kept dry and free from liquid ether. It is wise always to protect the eyes and the face by keeping the eyelids closed and by covering the face, except for a small hole for the airway and the tip of the nose, with a rubber sheet (about seven inches square).

The administration of ether and air by the intratracheal route is described in another article, but it may be suggested here that in order to reduce cooling of the lungs the gas should be warm, it should be moist (to avoid loss of heat in the evaporation of water vapour in the alveoli), and the flow should not be too rapid. Magill's widebore rubber intratracheal tubes, in addition to other advantages, dispense with the drying effect of the return rush of ether-laden air which led to laryngeal and tracheal dryness when using narrow gum-elastic catheters in earlier methods.

Closed ether is still commonly used. Ormsby's bag, in which ether is evaporated from sponges, and Clover's inhaler, or various modifications such as Hewitt's, are valuable. The ether-air mixture is rebreathed, usually inhalation of pure air being allowed after every fifth breath. The rise in the carbon dioxide concentration in the rebreathed gas promotes vigorous respiration. The accompanying exaggeration of abdominal movement, however, may be a disadvantage; moreover the tendency to vasodilatation and even congestion may cause a tendency to hæmorrhage. It is fair to state that in skilled hands these faults are usually avoided. Certainly closed methods are less wasteful of ether than the open mask.

Ether excites free salivation and secretion of mucus which is prevented by atropine, and atropine reduces the danger of reflex cardiac inhibition. Dry pulmonary alveoli absorb ether and oxygen and excrete carbon dioxide very much more

readily than is the case when free secretion of mucus is present. Children tolerate atropine well.

For induction of anæsthesia ether is not pleasant. Actually after a few breaths the pungency of the vapour is hardly noticeable to the patient, but great care is essential in order to avoid a choking sensation in the first few inhalations, and coughing is often troublesome, particularly in cigarette smokers, until a late stage of induction. For these reasons it is usual to induce anæsthesia with some other method, with ethyl chloride, nitrous oxide, or one of the basal narcotics The administration of ether demands a free air-passage; because respiration is stimulated, nearly twenty per cent. of the air supply is replaced by ether vapour, and the tendency to vasodilatation and congestion of the upper air-passages speedily leads to a vicious circle if the oxygen supply is limited Therefore oral breathing with an oral airway is necessary in nearly every case.

Ether has a definite local anæsthetic effect on the larynx after administration for some minutes in moderate concentration, and in full anæsthesia abduction of the cords is promoted Although irritation of the lung epithelium occurs, careful use on the lines suggested above has shown that in healthy lungs this is not a serious matter. Nevertheless prolonged administration of concentrated cold ether-vapour appears to be harmful for the lungs, for the liver, and for the kidneys. It is noticeable that weakly individuals feel sick and uncomfortable for minutes or even hours after a short administration of ether which has lasted only two or three minutes, but strong and vigorous people who are not susceptible to the effects of drugs often are found to recover from a short administration as freely and as comfortably as if they had taken nitrous oxide. Ether is particularly useful for giving complete abdominal relaxation when

a simple general anæsthetic is required, and for this purpose it is probably still the best agent we possess.

Ether convulsions should be carefully distinguished from ether tremor. Much has been written on the subject in recent years but it is a notable fact that few anæsthetists of experience have seen a case. The condition is a serious one, but the cause is not recognized with certainty, and space is not available for an adequate discussion. It is doubtful if a case has ever occurred when using pure ether and when maintaining a good oxygen supply.

Ether vapour is inflammable but attention is drawn to the distinction between simple ignition of the vapour in air, and the enormously more serious detonation which ensues when ether vapour mixed with oxygen is ignited.

CHLOROFORM

Chloroform is still much employed in Scotland, not often in England, hardly ever in America. Strong opinions are held both by chloroformists and by those who would limit its use. In a short article only brief allusion can be made to some of the principles involved in its administration and to some of its advantages and disadvantages. Chloroform boils at 61° C., the liquid gives off vapour readily at ordinary temperatures, the vapour is much heavier than air, and when well diluted with air it is not unpleasant to inhale. Chloroform is a most powerful general anæsthetic agent; 2 per cent. of the vapour mixed with 98 per cent. of air will maintain surgical anæsthesia. It is not inflammable. Analgesia is produced before consciousness is lost. During induction there is a tendency for the cardio-inhibitory centre to be stimulated. Heart muscle and liver parenchyma are susceptible to its action and both heart weakness and liver degeneration may follow its use.

Whatever may be the theoretical considcrations, practice has shown that thc following points are of importance. Administration must be evenly regulated. As little as 4 per cent. in air has caused the effects of overdose. A free air supply or the addition of oxygcn is necessary, and if the brcath is hcld the mask must bc removed lest strong vapour collect under thc mask and an ovcrdose be inhaled at the next inspiration. To providc smooth administration and a good air supply, instead of the per-halational method used with ether, a *few* layers of gauze, or a singlc layer of lint, is placed on the mask, chloroform is dropped on the lint in one place drop by drop continuously and carefully.

Chloroform is not suitable for childrcn who are frail, for highly-strung nervous pcoplc, for those who are suffering from septic conditions (such as toxic throats and carbuncles), from post-influenzal debility, or from liver insufficiency or from starvation. Such patients may sustain serious damage such as prolonged post-anæsthetic vomiting, livcr failure or heart failure or cven sudden death Chloroform should never be given to a sufferer from diabetes.

But chloroform has certain special advantages. Operative bleeding from tissues is reducod; probably the diastolic blood-pressure is raised by slight vasoconstriction, and the systolic pressure lowered by cardiac weakening. In diathermy or cautery operations, or in endoscopy, whcn heatiog of the tissucs or electric sparks might lead to the ignition of an inflammable gas, chloroform is safer. In the presence of inflammatory disease of the lung (pneumonia, tuberculosis), when irritation of the epithelium or exaggerated lung movements are specially undesirable, chloroform and oxygen may be blown gcntly into the mouth or pharynx with less irritation and quiet breathing. The analgesia which precedes

unconsciousness renders dilute chloroform vapour particularly suitable for producing analgesia in midwifery, but a comparatively small increase in the dose will stop uterine contraction with the delaying of labour and the risk of uterine hæmorrhage.

The apparatus may be the simplest and the cheapest—the proverbial "rag and bottle." The need for even dosage is met by the Vernon Harcourt inhaler which in former days was widely used. Air is drawn by the patient over chloroform in bottles, the temperature of which can be raised by grasping it with the hand, and in which the temperature change is estimated by the variation in the specific gravity of the chloroform which accompanied the cooling or heating. Two small beads of different specific gravity rise or sink as the temperature changes. The apparatus gives weak vapour and the depth of anæsthesia is barely sufficient for modern laparotomies.

In Junker's inhaler, air or oxygen is blown through chloroform and then delivered into the mouth or under a mask. It has the merit of providing smooth anæsthesia, and the rich oxygen supply is a definite safeguard. Care must be always taken that the tubes are correctly attached to the chloroform bottle lest, by reversing the stream of air, liquid chloroform be blown into the air passages.

MIXTURES

The use of *nitrous oxide-oxygen-ether* is described in another article (p. 75).

Ethyl chloride is sometimes added to the nitrous oxide bag in dental work for a patient who is too robust for nitrous oxide to be completely effective.

Chloroform and ether form a true solution, the one in the other, and the more usual proportion is two parts of ether to one

part of chloroform. The mixture is administered either by the open method on lint, as in the case of pure chloroform, or by Clover's or Hewitt's inhaler *without the bag*. It must be remembered that E_2C_1 mixture depends upon the chloroform constituent for its anæsthetic action, and that it should be used as diluted chloroform. The ether stimulates respiration, but as it is weaker than chloroform and much more volatile, the anæsthetic effect of the ether is small. Therefore carefully regulated administration with plenty of air is requisite. During the war McCardie found that a mixture of one part of chloroform with sixteen parts of ether on the open gauze mask was a powerful and stimulating anæsthetic agent for healthy but nerve-wracked young soldiers.

DIVINYL ETHER

Attempts have been made to employ ethers other than diethyl ether, e.g. di-methyl ether. Divinyl ether has been given an extensive trial recently. The substance is a mobile liquid which volatilizes readily. With odour and action not unlike ethylene it is rapidly absorbed and excreted and it is not toxic in its effects. But a warning has been sounded as to possible injury in cases of liver insufficiency. Owing to its costliness and its volatility it is not convenient to administer the pure drug on an open mask. Divinyl ether is employed with oxygen in a closed circuit for rebreathing, or with nitrous oxide and oxygen (with or without a carbon dioxide absorber), or as a single dose anæsthetic in a bag, like ethyl chloride. Dissolved one part in eight parts of diethyl ether it is possible to use the open method. It must be remembered that the gas is highly inflammable, and that it does not keep well, so that fresh material should be used.

CHAPTER III

NITROUS OXIDE ANÆSTHESIA IN SURGERY

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CHAPTER III

NITROUS OXIDE ANÆSTHESIA IN SURGERY

SINCE it was employed in 1844 nitrous oxide has shared with ether (1846) the leading position in a long list of anæsthetics. In each of these cases the popularity of the anæsthetic has been largely due to its safety. In this article the use of nitrous oxide gas, its advantages and disadvantages, the indications for and against its use, the important and often misunderstood subject of cyanosis in relation to nitrous oxide anæsthesia, the technique and the signs of nitrous oxide anæsthesia will be discussed. Finally, although stress will be laid upon the continued value of nitrous oxide as a regular anæsthetic for minor surgery, it will he made clear that its use by inexperienced anæsthetists for major surgery is fraught with disappointment if not carried out boldly, and with danger if it is.

At the present time the few specialist anæsthetists who use nitrous oxide for major surgery are tending to adopt cyclopropane which even encroaches, although as yet but slightly, upon the use of ether, whilst nitrous oxide for minor surgery is challenged more seriously by the intravenous barbiturates, such as evipan and pentothal. The use of nitrous oxide will be diminished by these new agents, but they will not replace it. For many years to come nitrous oxide is likely to remain in favour for cases in which quiek recovery to normal is required.

The popularity of this agent has not been seriously challenged in dental work and in midwifery (subjects which are being dealt with in other articles); in fact its use in midwifery is steadily increasing.

ADVANTAGES AND DISADVANTAGES

Nitrous oxide has two merits as against more potent gases: (1) It does not form an explosive mixture with oxygen; a fact which explains its continued popularity. Ethylene would be probably of greater all round utility, but its use has led to many deaths from explosion. (2) During its use patients may be deprived of oxygen for short intervals without appreciable harm.

The advantages of nitrous oxide anæsthesia are:—

(1) Quick recovery. Because of this it may be given to ambulatory patients. In more extensive operations quick recovery reduces the amount of after-care needed, an important consideration when the nursing staff is depleted.

(2) Diminished incidence of nausea and vomiting. The problem of vomiting is extremely complex, dependent partly upon the personal idiosyncrasy of the patient, and no more follows a set rule than does sea-sickness. In prolonged anæsthesias the absence of vomiting is more marked and the general well-being of the patient more evident after nitrous oxide than after any other form of anæsthesia, but at times, after quite trivial operations under nitrous oxide, it is disappointing to find prolonged vomiting, whereas a severe operation under ether, or some other potent anæsthetic, in other cases, is at times not attended by this unpleasant sequel. But probably failures would have been even worse after ether.

(3) The gut functions normally more quickly after nitrous oxide anæsthesia than after any other form of anæsthesia, and there is less pain from gaseous distension.

The disadvantages of nitrous oxide anæsthesia may be summarized under four heads:—

(1) Most patients do not like an inhalation anæsthetic. In general, patients prefer to be anæsthetized by intravenous or some other form of basal anæsthesia, for example, avertin.

(2) There may be increased bleeding at the site of the operation. This is due to imperfect functioning of the heart consequent upon sub-oxygenation. Imperfect emptying leads to a damming back on the venous side with engorgement of the veins.

(3) Nitrous oxide is a weak anæsthetic and consequently for certain robust, plethoric and alcoholic individuals it is not strong enough to maintain unconsciousness unless profound asphyxia is achieved.

(4) For its use in major surgery the anæsthetist needs to be experienced, and perfect functioning of an accurate anæsthetic machine is absolutely essential.

INDICATIONS AND CONTRA-INDICATIONS

Nitrous oxide anæsthesia is indicated for minor operations, for example, for opening a whitlow, for carbuncle or avulsion of the nail; here the fact that it is the ideal form of anæsthetic for the ambulatory patient is an advantage. In major surgery it is recommended only when an experienced anæsthetist is at hand and when a quick recovery, with minimal after-effects is specially desired.

Contra-indications fall into two widely divergent groups which are, however, linked by the fact that in each case it is

the necessary introduction of the asphyxial element which renders the use of nitrous oxide anæsthesia undesirable. For the "anæsthetic resistant" or sthenic group which might include, for example, the typical naval commander and the international footballer, such a profound asphyxial element may have to be introduced that spasm of the laryngeal muscles and lack of oxygen to the respiratory centre may cause alarming respiratory arrest. In the other group are patients with a weak myocardium, for example, post-influenzal debility, exophthalmic goitre and prolonged toxicity from any cause. Here even a slight reduction of the oxygen intake causes a diminution of the cardiac output which, if not corrected, will lead to further sub-oxygenation and respiratory arrest without any evidence of muscular spasm or jactitation.

There are many conditions constituting contra-indication which might be removed and the patient fitted for nitrous oxide anæsthesia by adequate premedication

Cyanosis in anæsthesia.—In the days when open ether anæsthesia was in almost universal use, cyanosis was always a danger sign denoting respiratory obstruction, a condition to be avoided because of its dangerous potentialities and also because of the increased bleeding resulting from engorgement of veins, in its turn due to lack of effective movement of the thoracic pump. Cyanosis of nitrous oxide anæsthesia, however, is not due to respiratory obstruction but is often a necessary part of certain stages of the anæsthesia and is deliberately produced so that anoxæmia will accentuate the weak anæsthetic action of the drug. Nitrous oxide is carried in simple solution in the blood and does not combine with the hæmoglobin of the red blood corpuscles. The presence of nitrous oxide in the blood is not in itself responsible for the production of cyanosis except in so far as inhalation of this gas excludes oxygen from

the lungs, so preventing the reduced hæmoglobin from being oxidized. A person breathing a mixture consisting of 80 per cent. nitrous oxide and 20 per cent. oxygen is just as pink as one breathing air, i.e. approximately 80 per cent. nitrogen and 20 per cent. oxygen. If the mixture is altered to contain 90 per cent. nitrous oxide and 10 per cent. oxygen, i.e. the proportion of nitrous oxide is increased at the expense of the oxygen, the partial pressure of oxygen in the mixture may be insufficient fully to oxygenate the patient's hæmoglobin. 100 c.cm. of average human blood contains 15 grammes of hæmoglobin. Irrespective of the amount of oxidized hæmoglobin in the blood a cyanotic appearance cannot result unless 5 grammes of reduced hæmoglobin is present in each 100 c.cm. of blood. It therefore follows that if, on account of anæmia, the hæmoglobin in a patient's blood is reduced to say, one-third of its normal, i.e. 5 grammes per 100 c.cm., that all the hæmoglobin in a patient's blood would have to be in a state of reduced hæmoglobin before he could take on a cyanotic appearance. This is manifestly impossible since before this state of things could come to pass the patient would have stopped breathing because of lack of oxygen to the respiratory centre. The understanding of this point is of vital importance, however, if the error of using colour as a guide to nitrous oxide anæsthesia in anæmic patients is to be avoided. A markedly anæmic patient will die without becoming cyanosed. Even under ordinary conditions the oxygen-carrying capacity of the anæmic individual is markedly reduced, and if it is reduced still more by cutting down the oxygen intake in the inspired mixture, respiratory arrest due to anoxæmia of the respiratory centre will take place before there is enough reduced hæmoglobin present in the blood to cause cyanosis.

Conversely, a plethoric man, with, say, 17 grammes of hæmoglobin per 100 c.cm. of blood, will be cyanosed when 5 grammes of this are in the reduced form even though the remaining 12 grammes are oxygenated. This amount of circulating oxygen is enough to support the vital functions of the body. Therefore it is possible for the colour of one of two patients inhaling the same mixture of nitrous oxide and oxygen to remain almost unchanged, whilst the other becomes blue. The depth of anæsthesia in the anæmic patient is, in fact, greater than that in the normal patient because of his poorer condition generally. Instead of becoming blue an anæmic patient becomes ashy-grey when the quantity of his reduced hæmoglobin rises.

Cyanosis almost invariably plays a conspicuous part in certain phases of nitrous oxide anæsthesia and is naturally alarming, yet this condition is not necessarily an indication of danger and is completely under the anæsthetist's control. The patient's colour can be changed back to bright pink within a matter of seconds and full consciousness may be restored within a few minutes. Many critics, who remain unmoved by profound and even dangerous unconsciousness produced by other forms of anæsthesia, provided the patient is pink, take strong exception to cyanosis in nitrous oxide anæsthesia, an attitude which can, in fact, be justified only upon æsthetic grounds.

Within limits, however, colour is a guide to the degree of anæsthesia. The fact that in an average patient a certain degree of cyanosis is incompatible with consciousness leads to change of colour being used, perhaps unconsciously, as a rough guide to the depth of anæsthesia in many cases, but that change in colour is not an essential guide is proved by the fact that such experts as Clement and McCarthy (Toledo, U.S.A.) and de Caux (London) can anæsthetize with nitrous oxide for major

operations even in cases in which it is impossible for them to see the patient.

SIGNS OF NITROUS OXIDE ANÆSTHESIA

Nitrous oxide is a weak anæsthetic agent and in order to obtain satisfactory anæsthesia it is necessary either to combine it with another anæsthetic, or to accentuate its weakly depressant qualities by the introduction of an asphyxial element. It is the only anæsthetic in common use during the administration of which the oxygen intake is reduced below that which is normally breathed, and the signs of nitrous oxide anæsthesia are largely those of oxygen lack. The signs are alteration in the respiratory rhythm, muscular, and eye signs, and colour changes in that order of importance.

Respiratory signs.—In light anæsthesia respiration is often irregular. If a painful stimulus is applied at this stage, there may be either a great increase in the rate and depth of respiration or a tendency to prolonged inspiration and breath-holding. Prolonged inspiration usually indicates light anæsthesia, and prolonged expiration deep anæsthesia. As anæsthesia deepens, respiration tends to become regular and automatic, but if oxygen reduction is continued until respiratory arrest occurs, this is preceded by a period of quick breathing until respiration ceases with the chest in the expiratory position. If the patient is lightly anæsthetized, quick breathing is probably the result of an operative stimulus, but it is important to remember that oxygen lack may cause respiratory stimulation. An occasional sigh indicates a desirable depth of anæsthesia.

Phonation may occur during either light or deep anæsthesia under nitrous oxide. During light anæsthesia it may be the result of reflex stimulation of the upper respiratory tract, for

example, the presence of blood or mucus or any other foreign body in the larynx, or it may be the result of painful stimuli to any part of the body. Phonation at this stage bears a relation to the stimulation caused by operative interference; on the other hand, during profound oxygen lack phonation may occur as the result of spasm of the laryngeal and pharyngeal muscles produced by anoxæmia. Phonation here bears no relation to operative stimulation. Sub-oxygenation leading to spasm of the laryngeal muscles causes irregular jerky inspiration, and there may be snoring, gutteral noises with prolonged expiration, or sobbing respiration. The treatment of this condition is to give oxygen.

Muscular signs.—During light anæsthesia the muscles, owing to reflex activity, may be rigid; with surgical anæsthesia the muscles are relaxed although they have a certain amount of tone. In profound anæsthesia the muscles are rigid owing to anoxæmia, and there may be spasm, jactitation or even opisthotonos. This spasm first appears in the small muscles of the tongue, but is easily overlooked there and its early manifestation may best be observed in the eye where spasm of the extrinsic muscles causes the eyes to be fixed eccentrically. In the anæmic, shocked, or heavily premedicated patient, muscular signs may be entirely absent.

Eye signs.—Early in induction if the eyelid is drawn back it will be found resistant and the appearance of the eye suggests consciousness because it focuses intelligently on any object. Later a quick horizontal movement develops, the rapidity and excursion of which diminish with deepening anæsthesia. In deep nitrous oxide anæsthesia the eyes become fixed and eccentric and the pupils widely dilated. For major surgery, when the patient has settled down to surgical anæsthesia, the pupil is small and central and the eye is fixed. For minor

surgery in a healthy patient the eyes should usually remain in a position where they are fixed just out of centre—generally downwards. The degree of anoxæmia denoted when the eyeball has just become fixed and eccentric is not enough to cause marked spasm of the larger muscles of the body and, if anæsthesia is maintained at this level, any small operation not requiring muscular relaxation may now be performed.

Colour changes.—As has been said, cyanosis as a sign of anæsthesia is unreliable. Its presence is no indication of danger, nor its absence a sign of safety. Clement, who has had much experience of anæsthetizing negroes, argues, with justification, that if, during anæsthesia, pulse, blood pressure and respiration remain normal, it is immaterial whether the patient be pink, purple or blue. Similarly, to take the extreme opposition example, the fact that a patient is not cyanosed is of little importance compared with the fact that his heart-beat or respirations have ceased.

PREMEDICATION

Pre-anæsthetic medication is a wide subject which must be touched on here. Most of the depressant drugs in common use in preparing the patient for an operation could, if given in correct dosages, produce unconsciousness, and even anæsthesia adequate for many operations. For example, hysterectomy can be performed under hyoscine and morphine alone; or under avertin or evipan. Respiratory depression, slowness of recovery and other factors make their sole use inadvisable, but if their possibilities are appreciated it serves as a reminder that, if given in smaller doses, the work to be done by any subsequent anæsthetic (e.g. nitrous oxide) is correspondingly reduced. For major surgery under ether or cyclopropane, pre-anæsthetic morphine is a comfort to the patient, but not a

necessity to the anæsthetist. In fact, the respiratory depression resultant on the combination of, say, cyclopropane or morphine, might embarrass him, but with nitrous oxide, morphine or a powerful substitute becomes an absolute necessity.

With nitrous oxide, anæsthesia is easily produced, muscular relaxation is not. Unconsciousness is largely dependent on anoxæmia resulting from reduction of inspired oxygen. Adequate oxygen supply, however, is essential for muscular relaxation. Fortunately for minor operations relaxation is not essential, but unless the reflex irritability of a patient is subdued by morphine, or its equivalent, it is impossible, using nitrous oxide alone, to achieve sufficient relaxation to perform an abdominal operation. For minor surgery where relaxation is not required, pre-anæsthetic medication is not essential, but it prepares the patient psychologically and undoubtedly facilitates induction and maintenance of anæsthesia.

The most useful drugs for this purpose are a combination of morphine and hyoscine in the proportion of 25–1, but for minor operations where the patient has to be ambulatory these should not be used, but an adult can be given aspirin 10 grains, or some other simple sedative the night before, and the dose repeated one hour before operation.

The administration of morphine must be accurately timed. An hour-and-a-half before a major operation a healthy man should be given $\frac{1}{4}$ to $\frac{1}{3}$ grain hypodermically, or a woman $\frac{1}{6}$ to $\frac{1}{4}$ grain. If, one hour after the morphine has been given, respiratory frequency is greater than 16 per minute, half the original dose should be repeated. If the respiratory rate is less than 12 per minute no more should be given, and if it is between 12 and 16 per minute the anæsthetist should use his own discretion as to whether he ought to give more.

Premedication and an accurate machine are essential for

obtaining adequate anæsthesia for major surgery with nitrous oxide. With other anæsthetics these are only luxuries.

NITROUS OXIDE FOR MINOR SURGERY

The apparatus necessary for the production of anæsthesia adequate for minor operations is simple, i.e. cylinders, bag, and face-piece. The training required to become efficient in this technique is relatively small. Anæsthesia may be obtained with either gas and air, or gas and oxygen. The technique for induction in each case is identical and for maintenance an adequate amount of air is admitted under the mask, or oxygen is run from a cylinder into the circuit. The results, for practical purposes, are the same. To prove that the anoxæmic element plays a greater part than the presence of a larger quantity of nitrous oxide, we have, for certain cases, administered mixtures of nitrogen (instead of nitrous oxide) and air for minor operations with results indistinguishable from the effect of nitrous oxide and air, or nitrous oxide and oxygen.

Technique for minor surgery.—Gas and air, or gas and oxygen are given according to the individual preference of the anæsthetist. The patient is made comfortable in the position most suitable for the operation. 100 per cent. nitrous oxide is then administered, the face-piece being held an inch or so from the face. The patient is encouraged to relax and to breathe normally, and the face-piece is gradually lowered on to the face. It should not touch the face until consciousness is lost. As soon as a normal patient shows signs of duskiness, as soon as any jerkiness or catchiness in respiration appears, or if the eyeballs become fixed other than in the central position, the face-piece should be taken off and the patient given one or two breaths of air. The face-piece must then be replaced immediately. It is not to be held away until the patient shows signs of

lightening anæsthesia If the supply of nitrous oxide is with held long enough for the effect of the intake of oxygen to be come apparent, embarrassing lightening may result Conversely, if a patient is lightly anæsthetized and is given pure nitrous oxide, as soon as he begins to show signs of deeper anæsthesia, the face piece should be taken off again and air administered before he shows any evidence of obvious oxygen lack

The beginner first anæsthetizes the patient too deeply and then, becoming alarmed, over oxygenates him so that he becomes too lightly anæsthetized, then again reduces him to deep anæsthesia With experience he learns to administer air before it is obviously needed, and nitrous oxide again before the patient shows signs of lightening anæsthesia, thus avoiding the see sawing type of anæsthesia in which the patient fluctu ates rapidly from deep to light A rough yet useful guide for the inexperienced administrator giving gas and air is to aim at keeping the patient s eyeballs fixed in a slightly eccentric position If the administration is continued until the eyeball is markedly eccentric, anoxæmic signs will probably have appeared in other muscles and the patient may be rigid or jactitating

There is usually enough tone of the pharyngeal muscles for the patient to keep his own airway clear Any sign of a jerky or catchy respiration suggesting an anoxæmic and spastic con dition of the muscles around the larynx is quickly relieved by the administration of air or oxygen

Induction for gas and oxygen anæsthesia is the same as for gas and air, but as soon as the patient shows any sign of oxygen want, a small quantity, say 5 or 10 per cent oxygen should be added *There is always a lag of about thirty seconds* (circulation time of blood) before any change in the mixture

becomes effective. Thus the anæsthetist must be prepared for anoxæmia to deepen first before the patient shows improvement in response to the oxygen.

In anæsthesia with nitrous oxide the sense of hearing is one of the last senses to disappear and one of the first to return Injudicious conversation should be avoided, but it is comforting to a patient if the anæsthetist talks to him during the induction and reassures him if he shows signs of anxiety. Conversation should be continued until the patient is deeply unconscious, since he might note early cessation and think the surgeon was about to start work. Any such alarms tend to make the course of anæsthesia less smooth.

NITROUS OXIDE ANÆSTHESIA FOR MAJOR SURGERY

The use of nitrous oxide for major surgery needs much more consideration than does its employment for minor work. The opening of an abscess in an average patient requires only a simple apparatus, little thought about premedication and a degree of skill and experience which would not tax the ability of most hospital porters. On the other band, to embark on a laparotomy with nitrous oxide as the sole anæsthetic agent requires careful premedication, a reliable machine, and courage, experience and skill acquired by few anæsthetists. A practitioner having recently had difficulty in obtaining, by the use of nitrous oxide, anæsthesia sufficiently tranquil to enable him to open a whitlow, may be excused for doubting that cholecystectomy can be performed under the same anæsthetic, especially since he has probably never seen any major operation under nitrous oxide anæsthesia. But the use of nitrous oxide anæsthesia in an adequately prepared and premedicated patient is a different thing from anæsthesia in a totally unprepared patient in the surgery or out-patients' department.

For major surgery the patient should be chosen with reasonable care and attention should be paid to pre operative preparation It must be made clear at the outset that it would be practically impossible, using nitrous oxide anæsthesia only, to remove the gall bladder from an alcoholic man who had not been premedicated

Nitrous oxide administered with enough oxygen to supply the basal metabolic needs of the patient has only a weak, in fact almost a negligible, anæsthetic action Therefore, in order to accomplish major surgery under this anæsthetic special points must be borne in mind

(1) The anæsthetist should not undertake to anæsthetize a patient with nitrous oxide alone for anything approaching major surgery without first having had considerable experience with this agent for minor surgery and without having seen an expert in the technique use it for major surgical work Nitrous oxide anæsthesia for major surgery is quite different from anæsthesia with, say, ether in that with a little experience and reasonable intelligence the learner can graduate quickly from anæsthetizing with ether for minor to major surgery, but even so he needs the advantage of seeing someone experienced in the method traversing similar ground Nitrous oxide anæsthesia for major surgery is a rarity in this country Enthusiasts who embark upon it without even having seen the correct technique are foredoomed to failure

(2) It would be nothing short of negligence to choose nitrous oxide anæsthesia for major surgery without having a machine worthy of the responsibility The anæsthetist must be able to use his machine to inflate the patient s lungs with oxygen under pressure should occasion arise, and the machine should also be capable of delivering accurate mixtures of nitrous oxide and oxygen

(3) Adequate premedication is essential.

(4) The method known as "saturation" must be used. This is the most discussed and the most criticized feature of nitrous oxide anæsthesia. Since nitrous oxide is a weak anæsthetic, muscular relaxation is secured by its use only after the preliminary conversion of an A1 into a C3 patient by secondary saturation. If, however, the patient is already C3 by reason of ill-health or if he has been made so by premedication, saturation is both unnecessary and inadvisable.

Saturation.—The effect of this is due not so much to any saturation of the tissues with nitrous oxide as to their profound deprivation of oxygen. The technique relies upon the heart continuing to beat for some time after the production of respiratory arrest by asphyxia. In anæsthesia for appendicectomy in an average man, 100 per cent. of nitrous oxide is administered as for minor surgery. This is continued through moderate, advanced, and profound oxygen lack, even to respiratory arrest. During this process respirations may at first be irregular from fear or excitement. With the onset of unconsciousness they first become regular, but as anoxæmia progresses, respiration become irregular, jerky, and later rapid and forced. The patient appears to gulp down his respirations. Eventually regular breathing stops. This may be followed by one or two snatchy inspirations which are succeeded by prolonged expirations. Respiration finally ceases with the chest in the expiratory position. The pulse changes in advanced asphyxia, becoming slow and bounding If, during this stage, the pulse becomes rapid, irregular or weaker it is a warning sign of cardiac failure and the asphyxia must be relieved by immediate administration of oxygen Muscular tone is present in light anæsthesia, and is succeeded during asphyxia by rigidity, spasmodic contraction of the arms and legs, and even

opisthotonos. The eyelid and conjunctival reflexes disappear with progressive asphyxia, and the movement of the eyeballs finally stops, the eyes becoming markedly eccentric—generally deflected downwards and sideways, with the pupils dilated the maximal size. The face becomes swollen and any previous expression of peace or relaxation changes to one of anxiety. Even after this extreme condition is produced the patient will generally make one or two efforts at inspiration after a pause of varying length. It is essential that when he begins to breathe again a mixture containing oxygen should be administered. The probability of the patient himself initiating such respiratory movements must not be relied upon. The anæsthetist should keep his finger on the patient's pulse, and if a slow bounding asphyxial pulse quickens, or if it becomes irregular, oxygen must *at once* be administered under pressure sufficient to inflate the patient's lungs. If this is not done the heart may fail before the patient makes any attempt to breathe again.

The effect of administering oxygen to a patient in this condition must be appreciated in order to get the best results from the method. Even if the patient were about to breathe again, the administration of oxygen would delay any attempt he might make at respiration. The lack of respiratory effort thus continued may be an added anxiety to the inexperienced administrator. The first signs that the oxygen administered has become effective are a return of the pulse to normal, a diminution in the size of the pupils, and a return of the eye to its central position. These results of oxygen are almost immediate and may occur even while the patient is still almost black in the face and is not breathing. When these improvements are observed, any anxiety to administer more oxygen must be repressed or too much may be given and the patient overstimulated. Improvement in facial colour quickly follows.

The previously taut muscles relax. Finally the patient breathes. By this time the shock of severe oxygen lack will have changed many previously A1 patients to C3.

Provided that adequate oxygen is administered, respiration will now become regular, but the proportion of oxygen which should be administered depends on the individual patient and on the operation to be performed. However, it is generally possible to give enough to keep the patient pink. In severe operations, anæsthesia is maintained with oxygen at a certain percentage, but as time goes on this amount may have to be considerably increased. This may be due to two factors (1) that the tissues use up any reserve oxygen they may have, and (2) that the patient becomes gradually and progressively shocked through oxygen lack and the surgical procedure. The successful outcome of saturation depends to some extent on the nerve of the anæsthetist. If it is carried through thoroughly the picture is alarming and unpleasant. If, on the other hand, the saturation is inadequate, anæsthesia is liable to be unsatisfactory owing to muscular rigidity or vomiting.

After saturation the patient may still not be sufficiently relaxed, and the whole process may have to be repeated. During this secondary saturation there is temporary anoxæmic muscular rigidity. The phenomena occurring during secondary saturation are very similar to those in the first saturation, except that the patient is not so fit, and muscular rigidity and opisthotonos do not generally play such an important part.

If, during the performance of the operation, the patient shows signs of lightening anæsthesia, the supply of oxygen can be cut off altogether until slight asphyxial symptoms appear. A breath of oxygen can then be given, and after this a mixture containing the proportion of oxygen which is considered the correct amount for the case in question. If, when the patient

is deeply anæsthetized, retching or swallowing occurs, it is a sign of oxygen lack which, if persisted in, will lead to vomiting. The *treatment is to give oxygen.*

Once the patient has been subdued by saturation the nervous irritability is reduced and he can often be kept pink and relaxed on, say, 10 per cent. oxygen. On this mixture, without previous saturation, muscular rigidity certainly, and possibly retching, and ever struggling would have been a feature of anæsthesia.

In surgery of intermediary importance where muscular relaxation is not essential it may not be necessary to "saturate" the patient. He can be given pure nitrous oxide until his respirations become quicker as the result of oxygen lack. Then a small percentage of oxygen can be administered with the nitrous oxide and the patient can generally be maintained at a steady level of anæsthesia

Saturation is justified only if the lack of after-effects warrants the increased risks it involves The temptation to accomplish the difficult feat of anæsthetizing for a major operation with nitrous oxide is not sufficient reason to expose the patient to any increased risks New drugs are making even slight risks less and less justifiable since relaxation of muscles can be produced with greater ease and with less danger with the help of agents such as avertin and cyclopropane, so much so that it is highly probable that the use of nitrous oxide for extensive major surgery will die out

For success with major surgery the intelligent co-operation and tolerance of the surgeon is essential. Those who like to operate on a patient with completely relaxed abdomen will never do good work under the conditions afforded by nitrous oxide, but there are surgeons who are so impressed by the good condition of the patient after nitrous oxide anæsthesia that

they are willing to put up with difficulties during the actual performance of the operation so that the patient shall reap the possible benefits afterwards. It is evident that really satisfactory team work is necessary for the adequate performance of nitrous oxide anæsthesia for major surgery. The surgeon must be prepared to be interrupted now and again, and he will seldom be afforded operating conditions so satisfactory as can undoubtedly be provided by the use of deep ether, or spinal anæsthesia.

NITROUS OXIDE AS A BASAL ANÆSTHETIC

Nitrous oxide is often given *following* avertin and barbiturates but as a contrast the opposite order may be employed. We have anæsthetized some cases following the method of Organe using the nitrous oxide as the basal anæsthetic in this way. Nitrous oxide with enough oxygen to supply the basal metabolic requirements of the patient is continued throughout the operation, and evipan or pentothal is given to procure any necessary relaxation. The results in a small number of cases are encouraging enough to warrant further trials.

NITROUS OXIDE—OXYGEN—ETHER

The nitrous oxide-oxygen-ether sequence should be mentioned if only to clear up a misapprehension. Generally speaking a smoother and more uniform anæsthesia can be obtained by administering ether from a machine than by pouring it on an open mask. Anæsthesia is first induced with nitrous oxide and since the gases can be made to flow either over or through the ether, the percentage of ether vapour administered can be gradually increased and then kept constant by means of a lever on the ether bottle. In addition, this constant flow of gases prevents the accumulation of carbon dioxide, which probably

occurs in the open method of administration, when the mask is surrounded by a cone of towels. When ether vapour is conveyed to the patient by gases from a machine, the nitrous oxide present in the mixture plays little part in the resulting anæsthesia and almost identical results could be obtained if, instead of nitrous oxide and oxygen, compressed air were used as a vehicle. The writers have often heard an anæsthetist tell a surgeon that the patient was having nitrous oxide with a trace of ether or with minimal ether, in a case in which the nitrous oxide was bubbling vigorously through the ether bottle. The anæsthesia in such a case is, for all practical purposes, due entirely to the ether. If the McKesson method of saturation has been performed, as described, and if operating conditions are still not satisfactory, or if the patient's condition has first been reduced to C_3 by any other means, such as premedication, hæmorrhage or shock, only a small percentage of ether will need to be added to nitrous oxide and oxygen from a machine to provide adequate relaxation.

CHAPTER IV

BASAL ANÆSTHESIA

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BASAL ANÆSTHESIA

BASAL anæsthesia aims at the comfortable production of unconsciousness (preferably in bed), and a sufficient depth of narcosis to enable subsequent surgical anæsthesia to be obtained and maintained by the superimposition of nitrous oxide and oxygen, or a small amount of ether or chloroform It is important that no basal anæsthetic, with the exception, in certain cases, of evipan or pentothal, should be used in a dose sufficiently large to produce full surgical anæsthesia without any additional inhalational or other anæsthetic being required. Such a dose may produce signs of profound medullary depression, namely, slow pulse-rate, fall of blood pressure, slow, shallow respiration, and anoxæmia.

ADVANTAGES

The advantages of basal anæsthesia are briefly as follows:—

(1) Psychic. The production of unconsciousness in bed can be arranged in such a way that pre-anæsthetic apprehension is minimized, and the ordeal of induction of inhalational anæsthesia is entirely eliminated. The importance of this, particularly in the case of children and of nervous and highly-strung adults, can hardly be over-estimated.

(2) Subsequent full surgical anæsthesia can often be maintained with the use of gas and oxygen alone. If it is necessary to use ether or chloroform to obtain deep anæsthesia, small

amounts usually suffice. Ether, instead of being the structure of anæsthesia, becomes more like an adjuvant, to be used for brief periods during which deep anæsthesia is necessary.

(3) The post-operative period is one of greater comfort and well-being for the patient. Amnesia often persists for several hours after operation, although patients will often take drinks and talk apparently rationally during this period.

(4) The patient is not subjected either to the harmful biochemical changes (e g. in the blood) produced by the administration of ether or chloroform in quantity, or to the strain thrown upon the liver and kidneys in excreting these drugs.

(5) Post-operative vomiting is usually slight, both in amount and in duration, and thus the immediate post-operative period is made less unpleasant for the patient.

(6) The occurrence of post-operative respiratory complications of anæsthesia is reduced.

DISADVANTAGES

There are certain disadvantages of basal anæsthesia, although theoretically none of them is insuperable.

(1) The use of basal anæsthesia involves the spending of a considerably increased period of time by the anæsthetist on each case. It is always advisable for the anæsthetist to examine the patient prior to the administration of a basal anæsthetic, both to choose the particular drug best suited to the needs of the particular patient and operation and also to ascertain the presence of any complicating disease which may influence the decision as to the dosage required. Furthermore, the preparation of the solutions of the various drugs commonly used, unless this task may *safely* be delegated, requires anything from five to twenty minutes.

(2) A patient who has had a basal anæsthetic usually requires a long period of individual nursing care after returning to bed from the operating theatre. This does not imply that such a patient requires greater care than if basal anæsthesia had not been used, but merely that the same care, e.g. of the airway, is necessary over a longer period of time, owing to the persistence of amnesia, which, in many cases, may be extremely deceptive, as is well illustrated by the following example:—

A young medical colleague, to whom I had administered avertin and gas and oxygen for an orthopædic operation, awoke in due course and soon convinced his nurse that he was completely rational. He asked for, and was given, a cigarette, which he lit and began to smoke. The nurse, thinking that he was safely round, left the room. When she returned a few minutes later, the patient was fast asleep, and the bedside tablecloth was on fire. When the patient again awoke, he had no recollection whatever of asking for or smoking a cigarette.

(3) The administration of the superimposed inhalation anæsthetic is rendered more difficult by the previous administration of a basal anæsthetic. Although there are exceptions—basal anæsthesia is a godsend to the anæsthetist when dealing with the exceptionally robust or alcoholic patient—this is a truism for the average patient. First, the administration of gas and oxygen without cyanosis requires more skill than the administration of ether, and secondly because, if basal anæsthesia *is* used purely for psychic reasons and ether is superadded, some patients are apt to suffer from what may aptly be called "frozen sleep." A plane is reached at which the patient has every appearance of being deeply anæsthetized. Respiration is slow, shallow, and regular, the conjunctival (sometimes also the corneal) reflex is completely absent, but muscular rigidity, particularly in the rectus abdominis, persists. Surgical stimulation does not, however, produce that reflex respiratory stimulation usually associated with light

anæsthesia, and the situation sometimes approaches an *impasse* to overcome which taxes the resources of the anæsthetist. The usual method is to administer carbon dioxide, because the mere administration of more anæsthetic is ineffective unless the respiratory volume is increased.

After the administration of a basal anæsthetic, the eye reflexes become a comparatively unreliable guide to the depth of anæsthesia.

(4) It might be said that a basal anæsthetic is fraught with danger because once administered, it is uncontrollable. Careful dosage, a watch for any signs of idiosyncrasy, as shown by an unusually profound effect early in the administration, and, if necessary, bold employment of antidotal stimulants, make basal anæsthesia controllable to a degree which refutes this statement.

DRUGS AND METHODS OF ADMINISTRATION COMMONLY USED

The rapid development, during the past eight years, both of the technique, and also of the ever-increasing public demand for basal anæsthesia, has resulted in the production of a large number of drugs for this purpose, which fall into three main groups:—(1) Avertin. (2) Paraldehyde. (3) Barbiturate derivatives. The following methods of administration of basal anæsthetics are commonly used:—(1) Per rectum—avertin, paraldehyde. (2) By the mouth—nembutal. (3) By intravenous injection—evipan, pentothal, nembutal.

COMPARISON OF DRUGS

The introduction of these drugs (except paraldehyde) has been so recent that opinion has not yet crystallized as to their relative merits and demerits. For this reason, only a brief account of the more commonly used drugs will be attempted.

AVERTIN.—Dosage: 0·075 to 0·1 gramme per kilogramme of body weight (depending on the condition of the patient) administered per rectum as a 2½ per cent. solution in distilled water thirty minutes before the time of operation. A disadvantage is that the preparation of the solution requires time and care, and that it must be freshly prepared for each case. The advantages of avertin are:—(1) Induction resembles the onset of natural sleep, and excitement is rare. (2) It is practically odourless.

The action of avertin is effective for two to four hours, and it is well tolerated by children.

PARALDEHYDE.—Dosage: The usual dose is 60 grains per stone of body weight, up to a maximum of 480 grains, a dose which should only be exceeded with great caution (Langton Hewer, 1937). Paraldehyde is administered per rectum as a 10 per cent. solution in normal saline. It is sometimes claimed that paraldehyde is safer than avertin, on the grounds that it has less depressant effect on the blood pressure and on the respiratory centres. Even if this controversial statement is correct, the difference is so slight that it is greatly outweighed by the disadvantages of paraldehyde, which are:—(1) The peculiarly offensive odour, which is particularly unpleasant for the attendants of the patient. (2) Excitement during induction and restlessness during recovery are more frequen than with avertin. Paraldehyde is effective from three t eight hours after administration.

Contra-indications to the use of avertin or paraldehyde:—

(1) Operations on the rectum, colon, or anus unless a previously performed colostomy is available for administration of the solution.

(2) The presence of pathological conditions in the rectum or colon.

(3) The presence of moist sounds in the lungs, however caused. The reason for this is that the slight respiratory depression normal under these drugs, may cause a dangerous increase in any pre-existing pulmonary secretion.

(4) Whenever it is impracticable to obtain or to estimate the body weight of the patient.

(5) Prior to the administration of any anæsthetic which may produce a fall in blood pressure, as for example high spinal-block, or chloroform, thereby avoiding a possibly severe or dangerous degree of anoxæmia.

(6) Whenever a rapid recovery from anæsthesia is desirable. In such a case, a more transient basal anæsthesia may be obtained by the use of a more rapidly eliminated barbiturate preparation.

THE BARBITURATE GROUP.—So many drugs of this group are used as basal anæsthetics that description will be confined to three of the more commonly used, namely, nembutal, evipan-sodium, and pentothal-sodium. Nembutal may be administered either intravenously, by the mouth, or in the form of suppositories per rectum.

Technique for intravenous administration of nembutal. Pre-operative medication.—Adult patients should be given morphine $\frac{1}{6}$ grain one hour before operation. This is a notable difference from the technique required for the administration of avertin, which should never be preceded by morphine. It has been proved, however, that a preceding dose of morphine gives a bigher degree of vital reserve than when a barbiturate alone is used to produce basal narcosis. Each ampoule of nembutal contains $7\frac{1}{2}$ grains and the only preparation necessary is to inject 10 c.cm. of sterile distilled water into the ampoule and shake for a few moments until all the powder is dissolved. The solution is then withdrawn into the 10 c.cm. syringe.

An intravenous puncture is made with a fine needle fitted to the syringe, and the injection begun. This is the only difficult part of the procedure, as injection must only be made at the rate of 1 c.cm. per minute, yet it must be a continuous process to diminish the risk of coagulation around the point of the needle. Severe cramp is liable to occur in the fingers of the administrator if more than 4 or 5 c.cm. are required to produce unconsciousness.

The dose injected is that required to produce unconsciousness plus 1 c.cm.—i.e. injection is continued until a patient stops counting aloud, 1 c.cm. more is injected, and the needle then withdrawn.

It is found that the average requirement is about 5 or 6 c.cm. The maximum dose recommended is 8 c.cm., and it is stated to be dangerous to exceed this limit, even if the patient is not unconscious, as larger doses of nembutal cause circulatory depression.

The clinical picture of the patient from this point onwards, and the subsequent procedure of preparation for operation and full anæsthesia, is identical with that described for avertin.

Technique for oral administration of nembutal.—Capsules of nembutal for oral administration each contain 1½ grains. One hour before operation an adult patient is given morphine, ⅛ grain by injection, and two capsules of nembutal by mouth. In the case of children morphine is omitted, and the following doses can safely be used:—Aged two-and-a-half to three-and-a-half years, 1 grain, either in a small capsule by mouth or as a suppository per rectum, forty-five minutes before operation. Aged three years and upwards, 1½ grains, forty-five minutes before operation. Unfortunately, the action of nembutal by the mouth or rectum shows a capricious individual variation, which limits the use of what would otherwise be

almost the ideal method of inducing anæsthesia. In satisfactory cases the effect is similar to that obtained by intravenous administration, i.e. the production of complete unconsciousness. In others complete amnesia is obtained, although the patient appears to be conscious; in a few cases it fails to produce more than a feeling of drowsiness.

Complications during or following the use of nembutal.—(1) The signs of overdosage are the same as those described for avertin, together with the production of pulmonary œdema. Treatment is similar, with the addition of the injection of atropine $\frac{1}{60}$ grain to combat pulmonary œdema.

(2) Care must be taken to avoid leakage of the solution outside the vein during injection, as this results at the least in a painful arm, and at the worst in sloughing at the site of puncture.

(3) Restlessness: This occurs in a small percentage of cases during both induction and recovery periods. It is more common in children than in adults.

(4) Headache: This occurs in 8 to 10 per cent. of cases. It rarely lasts more than twenty-four hours, and is usually well controlled by the administration of phenacetin, aspirin, and caffeine.

Contra-indications to the use of nembutal.—(1) The presence of moist sounds in the lungs, whatever their origin. This is of the greatest importance, as large doses of nembutal tend to cause pulmonary œdema.

(2) Low blood-pressure and cachexia.

(3) Severe disorders of renal function, and particularly uræmic conditions. Although glomerular function is little disturbed by the administration of nembutal, the total fluid output of the kidneys is depressed for the first twenty-four to thirty-six hours following.

(4) Inability to find a vein suitable for administration by the intravenous route. In practice, this means children under the age of five years and the obese. Strictly this is not a contra-indication, as these patients may be given nembutal by mouth, but it is a condition usually encountered too late to permit of administration by other routes.

EVIPAN SODIUM AND PENTOTHAL SODIUM.—Evipan and pentothal differ from other basal narcotics in two important respects:—

(1) They are broken down with great rapidity by the liver, and excreted as barbituric acid. In practice, this means that their effects are rapid, but transient. Consciousness is often abolished by 2 or 3 c.cm.

(2) This transcience of action increases the safety margin of the dosage and enables the administrator, in certain selected cases, to "push" the drug until surgical anæsthesia is obtained without the addition of any inhalation anæsthetic. Jarman and Abel (1936) have devised an ingenious three-way tap for continuous maintenance of surgical anæsthesia by adding evipan as required to a glucose-saline intravenous infusion.

Evipan is administered as a 10 per cent. solution in sterile distilled water, and pentothal as a 5 per cent. solution, both being prepared as previously described for nembutal.

Dosage and technique of administration.—Patients between the ages of 16 and 60 years may receive as premedication omnopon, $\frac{1}{3}$ grain, plus scopolamine, $\frac{1}{150}$ grain, administered one hour before operation. No premedication should be administered in short cases in which operation is to be performed using evipan or pentothal as an anæsthetic. Examples of such cases include avulsion of nails, iridectomy, reduction of fractures, dental extractions. Administration should be carried out at a rate not exceeding 1 c.cm. every fifteen

seconds. A safety pause of at least one minute should be made after the injection of the first 3 c.cm. This pause, which should always be rigidly observed, gives time for the 3 c.cm. to circulate in the blood-stream. Any individual idiosynerasy to the evipan or pentothal will then become apparent before a dose sufficient to cause dangerous symptoms has been administered. After this pause injection is slowly continued at the same rate until respiration becomes automatic. This usually requires about 5 to 8 c.cm. of evipan or pentothal, but the only reliable guide to dosage is the reaction of each individual patient. The administrator should never become so engrossed in the actual injection that he neglects frequently to pause in order to survey the condition of the patient. Throughout the administration an assistant or nurse must be deputed to take eare of the maintenance of a clear airway after consciousness is abolished. This is of paramount importance, as, if neglected, and the slightest trace of asphyxia supervenes, it precipitates an intense muscular spasm, and a vicious circle of dangerous respiratory obstruction may rapidly become established. If these three points, namely, slow injection, "safety pause" during administration, and serupulous maintenance of a elear airway are observed, evipan or pentothal provide a safe and pleasant means of indueing basal anæsthesia, or light surgical anæsthesia. Negleet of all or any of these points make them two of the most dangerous drugs used in the practice of medicine.

Complications of evipan and pentothal :—

(1) Overdose. The signs are similar to those of overdose of ether, i.e. central respiratory paralysis, with subsequent circulatory failure. Owing to the rapidity of their elimination, overdose of evipan or pentothal, unless gross, or complicated by obstruction of the airway, tends rapidly to pass off. I have

twice overdosed patients with evipan, in each case as the result of a second administration of the drug when the original effect was wearing off. One patient was aged 5 years and the other aged 65 years. In both cases the pulse, although slow, was of good volume, and the patient's colour remained good. The treatment of an overdose of evipan or pentothal in which circulatory failure supervened would be:—(1) Artificial respiration. (2) Administration of CO_2 and oxygen. (3) Intravenous or intracardiac administration of coramine, 2 to 4 c.cm.

(2) Jactitation. During administration of evipan a certain number of patients develop jerky, clonic muscular tremors of the limbs, which may seriously interfere with the injection. Such tremors are rarer during the administration of pentothal. These jactitations usually occur if there is any obstruction to the airway, however slight, or if administration is too rapid, and always occur if the patient has been premedicated with atropine. If atropine is to be given to a patient also receiving evipan, it should be administered after the evipan.

(3) Headache. A few patients complain of headache after administration. The headache is definitely alcoholic in type and disappears in two or three hours.

(4) Restlessness. Many patients awake from evipan or pentothal in a condition (often on their own admission) indistinguishable from the noisy stage of over-indulgence in alcohol. Usually this soon subsides, but occasionally restlessness is severe. At the first sign of undue restlessness an adult patient should receive an intravenous injection of omnopon, $\frac{1}{3}$ grain, as it is easier to check the onset of restlessness than to control it when it once has been allowed to develop. Restlessness is more common in children than in adults, and is more common after the use of evipan than of pentothal.

(5) Reaction at the site of injection. This is a possible

complication of all intravenous medication, and great care should be taken to avoid contact of the solution with perivenous tissue. Pentothal is more powerful than evipan as an irritant of the tissues.

Special indications for the use of evipan or pentothal :—

(1) In patients suffering from respiratory diseases, in which irritating inhalation anæsthesia is contra-indicated. Evipan and pentothal do not cause any increase in the secretion of mucus, and do not irritate the respiratory system.

(2) For short operations in the region of the mouth, particularly for those which involve the use of the cautery or diathermy. In such cases the use of evipan or pentothal enables the surgeon to operate in a clear field, unencumbered by the necessary apparatus required for the administration of an inhalational anæsthetic, and without risk of explosion.

(3) Whenever an effective but essentially transient basal anæsthetic is required, as for example when an early return of reflex control and of consciousness are desirable after an operation.

Contra-indications.—(1) The presence of damaged liver function.

(2) In cases with a low blood-pressure. Evipan causes an initial, but transient, fall in the systolic pressure during administration. Pentothal does not produce so marked a fall in blood pressure, but produces more respiratory depression during administration.

(3) In cases of cachexia and dehydration. Patients suffering from either of these two conditions do not tolerate any of the barbiturates well.

(4) Inability to find a vein suitable for administration. It is rarely possible to administer evipan or pentothal to children under the age of five or six years, and often impossible in obese patients.

THE CHOICE OF DRUG FOR BASAL ANÆSTHESIA

Although the choice of drug must obviously be determined in each individual case by the happiest and safest possible blend of the comfort of the patient, the requirements of the surgeon, and the skill and experience of the anæsthetist, there are certain broad indications for the use of any one drug, or group of drugs, for producing basal anæsthesia. In general, when it is expected that the operation will be lengthy, and will require relatively deep anæsthesia, and when a long period of post-operative amnesia is desirable, avertin or paraldehyde are indicated. For short operations, and especially when the benefit of basal anæsthesia are desirable, and yet a comparatively rapid post-operative recovery is necessary, evipan or pentothal are indicated. Nembutal is placed roughly midway between these groups, although the present trend of anæsthetic fashion is towards lessening the differences between the other two groups by variations of technique and dosage, with a consequent diminution in the use of nembutal as a basal anæsthetic.

POST-OPERATIVE SEDATION AFTER BASAL ANÆSTHESIA

The use of intravenous omnopon in the extreme restlessness occasionally seen after evipan has been mentioned but, apart from this exceptional event, great care is necessary in prescribing sedatives for the immediate operative period. When restlessness necessitates a sedative, it is usually better to give morphine $\frac{1}{6}$ grain and, if ineffective, to give another dose of $\frac{1}{12}$ grain forty-five minutes later, rather than to administer $\frac{1}{4}$ grain as a single dose. The older the patient, the greater should be the care exercised in observing this precaution. Many of the fatalities which have been recorded following the use of basal anæsthetics have, in fact, been due not to the basal anæsthetic, but to a cumulative depressant effect pro-

duced by too large a dose of a post-operative sedative, particularly in elderly or debilitated subjects.

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CHAPTER V

ENDOTRACHEAL ANÆSTHESIA

By JOHN H. T. CHALLIS, M.R.C.S., L.R.C.P.

CHAPTER V

ENDOTRACHEAL ANÆSTHESIA

BEFORE undertaking the administration of an anæsthetic by the endotracheal route, it is important to understand how to pass an endotracheal tube, since its use may not only facilitate speed and efficiency in performing an operation, but also safeguard the patient from immediate or remote complications. It may therefore be well at the outset to mention a few instances in which the use of this type of anæsthesia is advisable or even essential to modern requirements. The four chief *indications* may be roughly classified as follows :—

(1) To ensure the safety of the patient by preventing foreign material from entering the respiratory tract;

(2) When difficulty or inability to maintain a perfect airway is anticipated or encountered;

(3) When the anæsthetist or his apparatus could possibly obscure or infect the field of operation; and

(4) When general anæsthesia is used during the performance of certain operations upon the chest. (This indication will not be further discussed, as this type of surgery does not normally come within the province of the general practitioner.)

In certain operations upon the mouth or nose there is the possibility of blood, foreign bodies or infected material entering the trachea, and even when the likelihood of this occurrence is only slight it is always wise to make use of endotracheal anæsthesia as a precautionary measure. Certain positions of

the patient upon the operating table may cause difficulty in maintaining a perfect airway, e.g., kidney operations and laminectomy, and here again the endotracheal method of *anæsthesia will be found invaluable in overcoming this* difficulty. It is also indicated for operations around or upon the head and neck, in which case it is desirable for the anæsthetist to have as little apparatus as possible in the vicinity of the operative field. It may, in fact, be stated that for the average major operation it is preferable always to pass a tube and ensure a perfect airway than to neglect this precaution and regret the omission when difficulties have arisen during the course of the operation.

After these somewhat sweeping statements in favour of intubation, details of the *contra-indications* to its employment will now be described. Endotracheal tubes should never be used for short minor surgical procedures, or even on patients undergoing major operations if the depth of anæsthesia necessary for passing the tube would be much in excess of that required for the actual operation. As an example, for amputation of the breast, which can perfectly well be performed under pure gas and oxygen, the passage of an endotracheal tube would, in the hands of a beginner, call for an unnecessarily deep degree of anæsthesia. Nevertheless, in the circumstances enumerated above under (1), (2), (3) and (4), the use of a tube is invariably advisable, irrespective of the magnitude of the operation.

It has not been found possible to compile a comprehensive list of operations for which the use of an endotracheal tube is or is not indicated, as so many outside factors must be taken into account, such as nasal obstruction, carious teeth, the condition of the respiratory tract of the patient, the duration of the operation, and the skill and speed of the

operator. These and many other points must be duly considered and it must then be left to the clinical sense and judgment of the anæsthetist to sum up the pros and cons and to make a final decision in the matter.

APPARATUS REQUIRED

Once having decided that the passage of an endotracheal tube is expedient, it still remains for the anæsthetist to select the most suitable method of passing it according to the operation to be performed. If possible, it is always advisable for him to employ the method to which he is most accustomed and in which he is most skilled. It may be well to mention here that approximately 80 per cent. of the complications which occur from the passing of tubes result from lack of skill on the part of the anæsthetist. Details of these complications will be given later.

Although there are numerous methods of passing endotracheal tubes, it is proposed to deal with only four, these having been selected because the first two have been found to be the simplest to master, and the latter two are useful in obstinate and difficult cases and do not involve the purchase of elaborate and expensive apparatus.

Firstly, the required equipment will include:—

(*a*) *Magill's endotracheal tubes.*—These tubes are made of rubber, and range in size from No. 00 to No. 10. Their walls should be as thin as possible without detracting from a certain necessary degree of stiffness, the whole tube being made on the curve. The lower or endotracheal end is cut on the bevel, and any sharp edges are carefully smoothed away. It cannot be too strongly emphasized that the selection of tubes should be

carried out by the proposed user, and he will soon learn to pick out those most suited to his purpose and liking, taking into consideration the weight, curve, size and tension of the tube wall.

(*b*) *Magill's forceps.*—These are intended for picking up the endotracheal tube in the oral pharynx after its passage through the nose, and guiding it into the trachea under direct vision of a laryngoscope. As the skill of the operator progresses, the use of the forceps for this purpose greatly diminishes, but they will still prove handy for inserting a gauze pack into the pharynx should this be necessary.

(*c*) *Magill's laryngoscope.*—Any pattern of modern construction will serve, provided it has a slot along one side, and provided also that a battery is contained in the handle. The use of a laryngoscope run off the main electrical supply is not recommended, as it is more liable to generate heat, and may even spark in the mouth if there is a faulty connexion or a burst bulb, and possibly cause an explosion owing to the presence of ether or cyclopropane. The most popular pattern of laryngoscope is one with two blades so that these may be interchanged according to whether the instrument is required for use in an adult or in a child. The presence of a rheostat in the handle serves no useful purpose, and this will probably be done away with in future models of the instrument. Careful examination of the blades is worth while to ensure that the lower end is sufficiently flat to support the epiglottis, but not so thin or so sharp as to cause damage to this or any other part of the pharynx or larynx.

(*d*) *Endotracheal tube connexions.*—These are of two patterns:—Magill's and Challis's. The connexion should be sufficiently large to fit tightly on the end of the endotracheal tube, while not in any way limiting the free passage of the respiratory

excursion. Usually four sizes of connexions will serve all ordinary purposes—adult, medium, small and very small.

METHODS OF INTUBATION

(1) *Blind nasal intubation.*—To aid the passage of an endotracheal tube, certainly for the beginner and perhaps also after experience has been gained, it is well to spray the nose, pharynx and larynx with 20 per cent. cocaine to which a small quantity of adrenaline has been added. This serves two purposes:—(*a*) It causes shrinkage of the mucous membrane of the nose; and (*b*) it diminishes or obliterates the pharyngeal and laryngeal reflexes, thus allowing the passage of an endotracheal tube at a much lighter stage of anæsthesia than would otherwise be possible. This cocainization can be carried out either before the onset of general anæsthesia or, in the nervous patient, as soon as anæsthesia has been established. Before proceeding to anæsthetize the patient, an endeavour should be made to ascertain which nostril gives the freer airway, this side accordingly being selected for insertion of the tube. When in doubt it is usual to choose the left nostril. Extension of the head does not facilitate the passage of a tube which is properly curved, and it is often necessary to place two pillows under the patient's head so as to produce slight flexion and thus avoid any tendency to hyperextension. A tube, with the connexion firmly attached, should be selected, the size being determined not by the age of the patient so much as by his physical condition and proportions, usually size 8 for men and size 7 for women. The lower or endotracheal end of the tube should be well lubricated, preferably with a heavy lubricant such as vaseline which does not tend to wipe off easily. The upper two-thirds should be left dry so that manipulation of the tube with the fingers is not hampered by their slipping on

a lubricated surface. The tube is passed horizontally into the predetermined nostril for about a quarter of an inch, and is then directed vertically downwards along what is obviously the normal air passage. Clumsiness and the tendency so often noted in students to endeavour to push the tube upwards towards the cribriform plate rather than downwards into the nasopharynx must be guarded against, as this not only results in failure but may also inflict extensive damage upon the internal structures of the nose. During the passage of the tube the anæsthetist usually stands slightly on the left side of the patient and advances the tube slowly and carefully until a free respiratory excursion is found to be passing through it. This generally occurs as soon as the tube has traversed the nasopharynx and passed behind the tongue. The left ear is applied to the connexion to assess the respiratory excursion, whilst the tube is advanced with the right hand, the index and middle fingers of the left hand meanwhile supporting the jaw. The little finger exerts slight pressure on the thyroid cartilage, and assists by moving the larynx a little sideways in order to facilitate the easy passage of the tube should this prove necessary. With the ear applied to the connexion, it is possible to follow down the line of greatest respiratory excursion, and should this diminish or fail the tube should be withdrawn for a short distance until respiration is again well established. The tube should then be advanced once more, its direction having been changed by rotating it to the right or to the left. If it appears to be passing constantly behind or in front of the cords, it may be necessary to flex or extend the head further by the addition or removal of pillows. No force should ever under any conditions be exerted, either in passing the tube through the nose or when its end is in the vicinity of the larynx, as this will in no way facilitate its passage and may do extensive

damage; in other words, any attempt to pass an endotracheal tube through closed or semi-closed cords is doomed to failure, and if persisted in will probably inflict gross trauma upon them. Should such a difficulty arise, anæsthesia must be deepened until all spasm of the larynx has been relieved.

(2) *Endotracheal intubation with the aid of a laryngoscope.*—This may be required under two conditions :—

(*a*) When the operation is to be performed on or immediately around the nose; and

(*b*) When the blind passage of a nasal tube has failed or is rendered impossible owing to nasal obstruction or to a growth in the vicinity.

First of all, before embarking on the use of a laryngoscope it is well to ascertain in detail the condition of the patient's teeth in order to guard, so far as is humanly possible, against any trauma to them. Secondly, the patient must be sufficiently deeply anæsthetized to ensure complete relaxation of the lower jaw and absence of laryngeal reflexes.

The laryngoscope is held in the right hand and its blade is introduced vertically downwards, the index finger of the left hand meanwhile grasping the teeth, or, in their absence, the gums, of the upper jaw, just to the left of the laryngoscope. The thumb of the left hand aids in retracting the upper lip, the middle finger being used to open the jaw and push the lower lip out of the way of the instrument If working in the mid-line, which is the easiest and most efficient method, the primary aim should be to get a good and straight view of the uvula, having first ascertained that the tongue is below the laryngoscope and centrally placed in relation to it. Having defined this position, the instrument is carefully advanced until a perfect view of the epiglottis is obtained, this being the second landmark in the procedure. Under no condition should

any advance be made until this point is assured to the complete satisfaction of the operator The epiglottis is then gently picked up on the flat end of the blade, care being taken not to advance the instrument more than about a quarter of an inch The handle of the laryngoscope is then elevated until a view of the larynx is obtained At this stage there is no further need for protection of the lips, and it is therefore advisable to change hands, keeping the instrument steady with the left hand and thus leaving the right hand available for any fine adjustments or manipulations that may be necessary in order to guide into the trachea the nasal endotracheal tube which has already been introduced and is lying on the posterior pharyngeal wall An alternative method is to insert a fresh tube directly through the mouth into the trachea, meanwhile looking down the laryngoscope to make certain that this tube has passed well and truly between the cords of the trachea In order to avoid any possibility of damage, it is important to exercise as much care in withdrawing the laryngoscope as in its introduction

(3) *Oral intubation through a London Hospital prop* —The same preliminary cocainization and anæsthetization is performed as in methods (1) and (2), but, prior to induction, a London Hospital prop (as modified by Baker, and covered with a layer of rubber) is inserted centrally between the patient's teeth or gums When full anæsthesia has been induced, a Magill endotracheal tube, size 7 or 8, with an extra thick wall to afford increased stability and thus prevent it from kinking, and with slightly more curve than in the type used for nasal intubation, is passed through the prop, the tube being, if necessary, assisted with the finger over the dorsum of the tongue Then, once again supporting the jaw with the left hand, manipulating the tube with the right, and appreciating with the left ear each respiratory excursion through the tube, it is possible in over

60 per cent. of cases to pass the tube directly into the trachea. For the beginner, this method is only recommended if nasal intubation proves impossible owing to the presence of one of the complications already mentioned. It was devised for difficult cases (e.g., when there were limitations or abnormalities in patients which prevented them from opening the mouth widely) in an endeavour to limit the use of the laryngoscope which is always liable to cause damage, even in the hands of the most skilled.

(4) *Nasal or oral intubation by means of finger manipulation* — With the object of further limiting the need for use of the laryngoscope, and as frequent failures have been observed to occur with method (3) owing, it is thought, to the difficulty experienced in supporting the lower jaw in edentulous patients, this method has been evolved and undoubtedly possesses a number of advantages. All preliminaries, including anæsthetization, are carried out as in methods (1), (2) and (3). The endotracheal tube can then be introduced either through the nose or mouth, whichever is more suitable, after which the anæsthetist, standing on the left side and facing the patient, introduces the index and middle fingers of the left hand into the mouth of the patient, passing the fingers sufficiently far down the throat to enable him to elevate the epiglottis with the index finger. The endotracheal tube is then carefully eased further through the nose or slipped through the groove between the two already introduced fingers until its lower extremity comes into apposition with the tip of the middle finger and can be moved by this finger into such a position that further introduction will cause it to pass smoothly into the trachea. Owing to the position of the operator it is not possible to verify the location of the tube by auscultation; therefore, before removing the fingers, its actual entry must

be confirmed by palpating the two arytenoid cartilages which should be posterior to it This method should not involve the patient in any trauma, but the same cannot always be said for the operator unless he is blessed with very long fingers and guards his hand from the upper teeth by some artificial means. Owing to this great disadvantage this method of intubation should be reserved solely for edentulous patients.

COMPLICATIONS OF INTUBATION

As already stated, the great majority of complications are due to inexperience, and undoubtedly the commonest is trauma to the internal structures of the nose caused by inadequate or inefficient lubrication of the nasal tube, by the use of undue pressure in an endeavour to pass a tube of too large calibre, or by trying to force a tube in the wrong direction. These errors in technique not only cause abrasion of the mucous membrane but quite commonly lead to hæmorrhage The blood will naturally conform to the laws of gravity and pass down into the pharynx or even into the trachea. Bleeding may also result from forcing the tube through a pad of adenoid tissue or from exerting too much pressure on the metal connexion. It is possible to cause damage to any structure of the pharynx or larynx by excessive pressure on the tube, and too much emphasis cannot be placed upon the fact that tubes should never be in any way forced, and the moment the slightest resistance is encountered, a different direction or other methods should be adopted Insufficient care in the use of the laryngoscope is an even more common cause of trauma than nasal intubation. Thus, since force of any kind is certain to lead to trouble which may not only present difficulty in making subsequent explanation to the patient but even involve the anæsthetist in litigation, the precautions detailed above

should be ensured with meticulous care before laryngoscopy is undertaken.

MAINTENANCE OF ENDOTRACHEAL ANÆSTHESIA

Once having mastered the art of passing an endotracheal tube, little if any difficulty should be experienced in maintaining a smooth and even anæsthesia. The necessary equipment consists of a short length of rubber tubing which is attached to the endotracheal connexion, an outlet valve, a Magill bag, and practically any type of apparatus suitable for the administration of vaporized ether, chloroform, vinesthene, or any of the gaseous anæsthetics.

Sufficient of the pre-selected narcotic is administered to maintain anæsthesia. The anæsthetic is passed to the patient through the Magill bag, the outlet valve being adjusted by increasing or diminishing the tension on the spring so as to produce distension of the bag on expiration and creasing of it on inspiration. If only nitrous oxide and oxygen is being used, it is an advantage to maintain a slightly increased intrathoracic pressure throughout the operation by adjusting the outlet valve so that the bag is kept continuously distended. In order to do this it is necessary to prevent the escape of gas which normally occurs around the endotracheal tube, and this is effected by packing moistened gauze around the larynx or, perhaps better still, by placing a strip of adhesive plaster over the patient's mouth and over the nostril not occupied by the tube.

The anæsthetist can now leave the patient to the care of the surgeon, provided he remains in a position from which he can watch the movements of the bag and thereby gauge the depth and regularity of the patient's respirations, establishing the stage of anæsthesia accordingly, deepening or lightening it as

necessity may demand. In order to prevent any tendency to undue cyanosis, it is important also to keep a constant watch on the patient's colour, which is best judged by inspection of the blood from freshly made incisions. In addition to this, a check should also be made periodically upon the rate, tension and volume of the pulse.

At the completion of the operation it is advisable to lighten the anæsthesia as much as possible before withdrawing the endotracheal tube. This can usually be effected by washing out the ether or other anæsthetic with oxygen and a small quantity of CO_2. The cough reflex is in this way re-established before the patient is returned to bed, and foreign material which may have collected in the vicinity of the trachea can thus be expelled spontaneously by the unaided efforts of the patient himself.

CHAPTER VI

SPINAL ANÆSTHESIA

By J K HASLER, M B , B S , D A

CHAPTER VI

SPINAL ANÆSTHESIA

MANY practitioners who have to give anæsthetics regularly feel quite at home when using open ether or a Boyle's gas and oxygen machine. Lack of experience and perhaps lack of knowledge prevents them from using spinal anæsthesia for cases in which it might be of great value. This article aims at setting forth in a practical manner the underlying principles of this form of anæsthesia. It is not intended as a complete guide to the subject and special forms, such as Kirschner's spinal-zone anæsthesia, are omitted. It is for the practitioner who feels that a spinal anæsthetic is sometimes indicated but who hesitates to embark on what is to him an uncharted sea.

Spinal anæsthesia consists in the introduction into the spinal canal of some suitable drug which, by temporarily paralysing the nerves with which it comes in contact, will produce anæsthesia and muscular relaxation over the area supplied by those nerves. It is possible by this means to anæsthetize the whole body or anæsthesia can be limited to a tiny area round the anus. The central part of the trunk can be anæsthetized leaving the extremities unaffected or unilateral anæsthesia can be produced in the lower half of the body. At the present day it is chiefly employed for operations below the diaphragm. For surgical procedures above this area it should be left to those who have special experience. Forty years ago, when spinal anæsthesia was in its infancy, the drug used was cocaine. Although extremely efficient as an anæsthetic it was abandoned

on account of its toxicity and its place was taken by synthetic drugs having a similar composition of which the most popular were stovaine and novocain. Of recent years percaine, a drug allied to quinoline, has been rapidly gaining popularity in this kind of work.

In giving a spinal anæsthetic two main procedures are necessary. First, a lumbar puncture must be performed and second, the anæsthetic solution must be injected, and subsequently distributed over the required area of the patient's spinal canal by suitable posture. In addition, the anæsthetist must consider the treatment of the patient before, during, and after the period of anæsthesia.

THE LUMBAR PUNCTURE

Spinal anæsthetics have been given both through cisternal and dorsal punctures. The method of choice is by lumbar puncture as there is a risk of injury to the cord if the injection is given above the first lumbar vertebra. For purposes of the puncture the patient may be placed on either side or in the sitting position. If the lateral position is desired the patient should draw the knees up and tuck the head down so as to flex the spine. If the sitting position is adopted the patient should sit sideways on the operating table and place the feet on a stool at the side of the table. The spine can then be flexed by making the patient bend his head down toward his knees. The skin should be prepared by painting with some suitable antiseptic solution such as iodine, picric acid, or spirit. When doing this it is an advantage to mark the level of the iliac crests. A line joining these crests will pass across the tip of the *fourth lumbar vertebra which is a useful landmark.* The puncture should be made in the middle line of the body but

before this is attempted the site must be accurately determined. Generally speaking the most convenient site for the puncture is between L_3 and L_4, as, if the patient is inclined to be stout the spine of L_4 may be difficult to palpate. With the index finger of the left hand the tip of the spine of L_3 is found and by moving the finger downwards the hollow between this spine and the spine of the vertebra below will be felt. At this point an intradermal wheal is raised with a small quantity of novocain solution and through the wheal one or two c.cm. of novocain are injected subcutaneously. This will provide sufficient local anæsthesia to make the lumbar puncture a painless proceeding. Next the lumbar puncture needle is inserted. There are various types of needle on the market and whatever type is used should have a sharp point. It should not be larger in diameter than necessary and size 20 by the standard wire gauge is a convenient thickness. The needle should be inserted in the sagittal plane of the body and if it contains a stilette this should be withdrawn as soon as the needle has entered for a distance of about one inch. This enables the anæsthetist to know the exact moment at which the needle enters the dura mater by the appearance of cerebrospinal fluid. The needle should be pushed in slowly and as soon as cerebrospinal fluid flows out a further push of about 1 mm. should be given to ensure that the whole of the bevel on the tip of the needle is inside the dura mater. If after passing deep to the subcutaneous tissue the point of the needle touches bone it usually means that the spine of the vertebra below has been reached. The needle should be withdrawn to a point just deep to the skin and inserted again in a slightly upward direction, i.e. to the cephalic end of the body. If the needle is pushed in up to the hilt without drawing cerebrospinal fluid it is usually an indication that the needle has deviated to

one or other side. It should be withdrawn to the subcutaneous tissue and pushed in again keeping strictly to the middle line. Several fruitless attempts to enter the space usually means that the approach to the spaee has been faulty. The needle should be withdrawn completely and inserted again at a slightly different position. If this fails the anæsthetist must make a fresh start at the space above. A trace of blood appearing from the needle is of no significance provided that it is followed by clear cerebrospinal fluid. But it is important that fluid should be obtained before the anæsthetic solution is injected or the anæsthesia will fail. The dry spine of the earlier writers was a myth. It simply meant that the needle had not entered the dura mater or possibly that its lumen had become blocked. Needless to state the lumbar puncture should be performed with proper aseptic technique. If the needles and syringes are placed in spirit they should be washed through with sterile distilled water before use. Sterile tap-water should not be used as the presence of alkali in it may interfere with the potency of the anæsthetie solution.

THE INJECTION OF THE ANÆSTHETIC

Before deciding on the particular solution and the quantity of it which it is proposed to inject it is as well to have a clear mental picture as to what happens to the solution once it is inside the spinal canal. There is no mystery about this; it is merely that the force of gravity comes into play. Inside the canal is a quantity of cerebrospinal fluid and any other liquid injected into this will rise or sink according to whether its specific gravity is less or greater than that of the cerebrospinal fluid. A certain amount of mixing will take place while the two liquids are finding their own level or if the anæsthetic

solution is injected forcibly. The only result of this will be that the anæsthetic solution is increased in volume while being decreased on concentration. This is sometimes done purposely by the anæsthetist when he withdraws the cerebrospinal fluid into the syringe which contains the anæsthetic solution (barbotage). It is true that some diffusion may also take place but this is a slow process and it is doubtful if it is of any practical importance. As gravity will therefore come into play when the solution is injected it is important for the anæsthetist to know the specific gravity of the solution which he proposes to use and how it compares with that of the cerebrospinal fluid. The specific gravity of the cerebrospinal fluid is variable and it is impossible to say for certain what it is in any particular patient without actually testing it. The range of variation is, however, not wide and in the average patient it can be taken as being between 1,004 and 1,007: that of water being taken as 1,000. Anæsthetic solutions which are heavier than this are spoken of as hyperbaric and those which are lighter are called hypobaric. Most of the solutions which are commonly used to produce spinal anæsthesia are hyperbaric but there are three which are hypobaric. These are the light percaine solution which contains 1 part of percaine to 1,500 parts of water, spinocain, and duracaine. The last two solutions are practically identical and they both contain some alcohol which makes them hypobaric. It is doubtful if they remain hypobaric for long once they are inside the spinal canal and there is some evidence to show that the alcohol rapidly dissolves out and the remainder of the solution then becomes hyperbaric. Bearing in mind the part played by gravity it will readily be appreciated that the distribution of the anæsthetic solution can be influenced by posture as soon as the solution has entered the spinal cord. Suppose for example that 0·5 c.cm. of the stovaine in saline

solution (sp. gr. 1,080) is injected between L3 and L4 in a patient who is sitting up. If he remains sitting for a minute or two after the injection the solution will sink to the caudal end of the canal and an area of low spinal anæsthesia will be produced. If on the other hand it is given with the patient lying on his side and he is kept in that position for about five minutes a unilateral anæsthesia will be produced with the under side affected. Or again if after injection the patient is at once moved from his side on to his back the anæsthesia produced will be bilateral and will affect a large part of the abdomen as well as the parts below. When considering the question of posture it is important to remember that the spinal canal is not a straight tube but has certain curves in it which run in an antero-posterior direction. A glance at the diagram will make this clearer than any description. Fig. 1 shows the spinal canal of a patient lying horizontally on his back. It will be seen that a hyperbaric solution injected in the lumbar region will naturally run downwards to the mid-dorsal region. Beyond this point it cannot go unless the patient is placed in a fair degree of Trendelenburg's position. A hypobaric solution on the other hand will tend to remain in the lumbar region. If after injection the patient is placed horizontally on his face the conditions are reversed. A light solution will run to the mid-dorsal region and a heavy one will remain in the lumbar region. It is therefore quite safe to let a patient lie horizontally after the injection of any solution as there is no risk of the anæsthetic reaching the phrenic nerves and paralysing respiration. Fig. 2 shows the spinal canal with the patient in the upright position. Here a hyperbaric solution will sink to the caudal end of the canal and produce a low spinal anæsthesia and a hypobaric one will run up the canal towards the brain. A deep Trendelenburg position will produce

the opposite as the heavy solution will flow towards the brain and the light one will run to the caudal end.

After a short time the solution is said to become fixed. This means that the anæsthetic has become used up by acting on the nerve tissue with which it comes in contact thereby

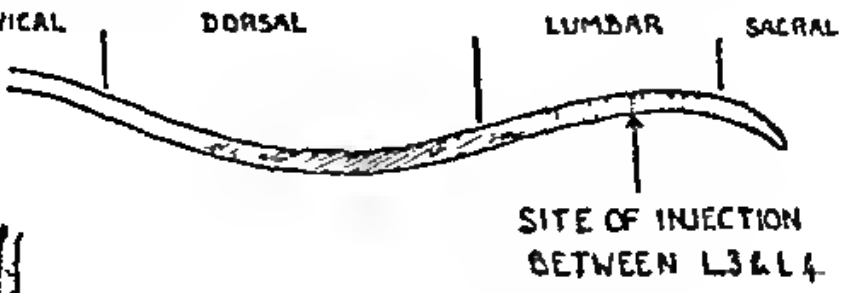

FIG. 1.

Diagram to show the curves in the normal spinal canal.

Above: With the patient lying horizontal on his back.

Below: With the patient in the erect position.

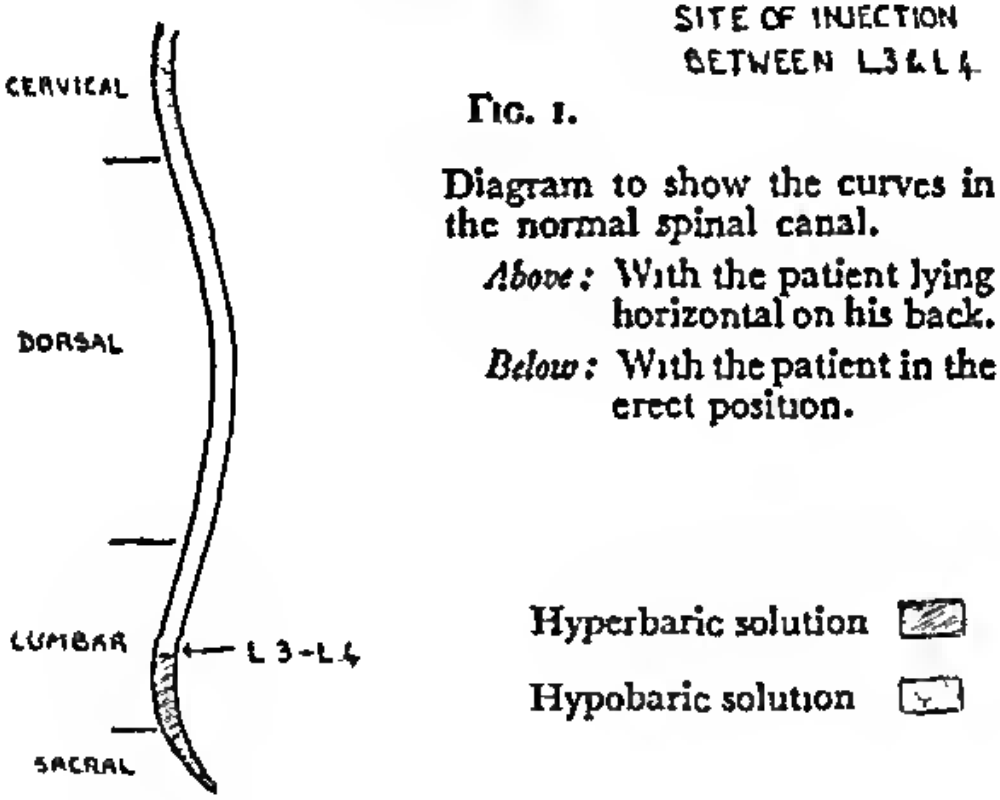

FIG. 2.

producing anæsthesia and muscular relaxation. When this has occurred no further change in posture will increase the area of anæsthesia. It is difficult to state definitely how long a solution takes to become fixed but it is probably anything up to ten minutes although some anæsthestists say half an hour. As a general rule it can be stated that once anæsthesia has become

properly established change of posture is unlikely to make any difference and therefore it is safe to put the patient in the Trendelenburg position if desired.

When the anæsthetic solution enters the spinal canal it affects three sets of nerves. These are the anterior roots, the posterior roots, and the branches of the sympathetic nervous system. Paralysis of the posterior roots produces anæsthesia and of the anterior roots muscular relaxation. Fortunately the anterior roots appear to be more resistant to the action of the anæsthetic than the posterior ones. As the solution runs from the lumbar region to the dorsal region it mixes with cerebro-spinal fluid and becomes diluted. There comes a point when it is too dilute to affect the anterior roots but is still concentrated enough to act on more of the posterior roots. If this were not so it would be difficult to produce anæsthesia of the whole body, as has been done, without paralysis of those important motor nerves, the phrenics. Another point to notice is that with a patient lying on his back a hypobaric solution will concentrate more in the anterior portion of the canal than in the posterior. Thus it has sometimes happened with this type of solution *that the muscular relaxation has been good while* anæsthesia has been deficient. Conversely a heavy solution will sometimes produce excellent anæsthesia while leaving some tone in the muscles over the area. The effect of the anæsthetic on the sympathetic nerves is to produce a fall in blood pressure by vaso-dilatation and to increase peristalsis in the bowel. It has sometimes been used in this connexion to treat paralytic ileus. When a low spinal is given only the para-sympathetic nerves are acted upon and the fall in blood pressure is so small as to be neligible.

DRUGS USED

Consideration must now be given to the various drugs which

are used for spinal anæsthesia and the solutions in which they are prepared. The majority of these are synthetic compounds allied to cocaine and the two which have enjoyed the most popularity are stovaine and novocain. Stovaine is supplied in ampoules which contain either 2 c.cm. of a 5 per cent. solution with 5 per cent. of glucose (Barker's solution), or 1 c.cm. of a 10 per cent. solution with 10 per cent. of sodium chloride (Chaput's solution). Both these are hyperbaric. Novocain, which is also known as procaine, ethocaine, allocaine, syncaine, neocaine, and planocaine, is also supplied in 5 per cent. and 10 per cent. solutions. In addition it is used in America in the form of crystals and these are dissolved in the patients own cerebrospinal fluid and are injected in this form, the quantity used depending upon the height of anæsthesia desired. Both stovaine and novocain have this disadvantage that anæsthesia cannot be relied on to last for more than an hour. With the object of prolonging its action novocain has been mixed with gliadin, and alcohol has been added to make it hypobaric. The two solutions thus prepared are known as spinocain and duracaine to which reference has been made previously. A heavy solution has been made in America by adding glucose to novocain and this is known as gravocaine. Of recent years a new drug, percaine, has been put on the market and this has become popular for spinal anæsthesia. Being powerful in action it can be used in a dilute form and the anæsthesia which it produces will last for two hours, three hours, or even longer. The advantages of this in long operations are obvious and by delaying the return of sensation it postpones the need for post-operative sedatives for the relief of pain. It is supplied in ampoules containing 20 c.cm. of the drug in distilled water (strength 1 : 1,500. sp.gr. 1,003), which makes it hypobaric, or in 3 c.cm. ampoules of a solution (1 : 200) to which 6 per cent.

of glucose has been added to make it hyperbaric (Sp. gr. 1,024).

INDICATIONS

It is not possible to give full and accurate details of the methods of using all these solutions in a short article but the following general principles can be stated :—

(1) For operations on the perineum and closed operations on the bladder and the urethra low spinal anæsthesia should be used. The injection should be given with the patient in a sitting position and a heavy solution should be used. The dosage should be as follows :—stovaine and novocain, 10 per cent. solutions, about 0·4 c.cm. and nearly double this if 5 per cent. solutions are used. With percaine and glucose 0·8 c.cm. to 1 c.cm. should be used for rectal cases and 1 c.cm. to 1·2 c.cm. for operations on the bladder. The patient should remain sitting for a minute or two after the injection.

(2) For abdominal operations the injection should be given with the patient lying on his side. If novocain or stovaine are used the amount should be nearly double that given for low spinal anæsthesia. Immediately after the injection the patient should be placed on his back. If heavy percaine is used about 2 c.cm. should be injected. If the hypobaric solution of percaine is used about 12 to 15 c.cm. should be injected and the patient should then be placed on his face for five minutes. At the end of this time he should be placed on his back with the head of the table slightly lowered. An alternative method when using the light percaine solution is to place the patient in the sitting position so that the anæsthetic when injected runs up toward the head. The same dosage should be given and at the end of the forty-five to fifty seconds from the time the injection is begun the patient should be placed flat on his back with the head of the table lowered. When using the heavy

solutions the patient should not be placed in full Trendelenburg's position until anæsthesia has become well established. A slight lowering of the head of the table is permissible however.

(3) If a unilateral anæsthesia is desired the patient should be on his side during and for five minutes after the injection. If a heavy solution is used the patient should lie on the side on which it proposed to operate and if a light solution is used this side should be uppermost. Dosage should be rather more than the dose for low spinal for operations on the leg, and for operations on the kidney the dose injected should be nearly that for full abdominal work.

PRELIMINARY TREATMENT

All patients who are operated on under spinal anæsthesia should have adequate premedication. Unless the operation is short or is an emergency it is not desirable that the patients should be fully conscious and within limits the sleepier they are the better. For one thing there is bound to be some degree of mental anxiety and for another it is difficult for a patient to lie absolutely still for any length of time on a hard operating table. The following form of premedication has been found useful when using spinal anæsthesia. One hour and a half before operation a hypodermic injection of omnopon $\frac{1}{3}$ grain and scopolamine 1/150 grain is given and followed half an hour later by a capsule of nembutal $1\frac{1}{2}$ grains by the mouth. If at the end of another half hour the patient is not asleep or drowsy a second capsule of nembutal can be given. With this premedication many patients, particularly the middle-aged, leave their beds asleep and wake up some hours later to find that the operation is over. Amnesia is also fairly common and although a patient may be able to answer questions on the

operating table he often has no recollection afterwards of having done so. If this premedication is considered excessive the nembutal may be omitted and only the omnopon and scopolamine administered.

Owing to the fact that the anal sphincter becomes paralyzed and peristalsis is increased under spinal anæsthesia it is undesirable that the patient should have liquid fæces in the rectum which might be voided during the operation. No aperient therefore should be given on the previous night though an enema may be administered if thought necessary. The stomach need not be kept empty as before the administration of a general anæsthetic and indeed it is sometimes an advantage before bladder operations to let the patient take fluid by the mouth up to the last minute so that the kidneys shall be excreting freely.

The anæsthetist should visit the patient before the day of operation to take his blood pressure and to explain what is to be done. The patient should be told that although he will not be put to sleep with general anæsthetic he will be made drowsy with a kind of sleeping draught.

CARE DURING THE OPERATION

As soon as the anæsthetic has been given a bandage should be placed over the patient's eyes. Cotton-wool may be placed in the ears but it is not so easy to shut out sounds with wool as is popularly supposed. If, however, the premedication has been adequate the patient will usually be so sleepy that sounds in the theatre will only leave a hazy impression. It is sometimes necessary at the start to tell the patient that although he may feel a sense of touch or of pressure he will feel no pain. Except when low spinal is used the patient must be kept with his head lower than his trunk during the operation. This keeps the vital

centres supplied with blood during the period of lowered blood pressure. Some anæsthetists minimize the fall in blood pressure by giving a hypodermic injection of ephedrine before injecting the anæsthetic, or it may be given intramuscularly immediately after the anæsthetic has been given. During the operation the anæsthetist should frequently palpate the facial or pre-auricular arteries. As long as either of these can be felt there is no cause for worry. If, however, the blood pressure falls so low that neither can be palpated an injection of ephredine ½ grain should be given intravenously with hypodermic syringe. This will produce an improvement within a minute or two. If the patient complains of nausea or vomits he should be encouraged to take deep breaths and the face should be sponged with a cold damp cloth. This sometimes coincides with traction on the mesentery or with the placing of a large pack in the upper part of the abdomen but is always transient in character. If for any reason the anæsthesia is not sufficient for surgical requirements or if it starts to wear off before the operation is completed then some supplementary general anæsthetic must be administered. A further injection of morphine or omnopon will sometimes allow the operation to be completed without the need for any general anæsthetic. It is not of much value given subcutaneously as it takes too long to act. For rapid action it should be given intramuscularly or even into a vein. It has occasionally happened that the anæsthetic has reached the cervical nerves in sufficient concentration to paralyze the phrenics. If this should happen artificial respiration must be performed until anæsthesia wears off and the patient can carry out his own respiration. With proper technique it should never happen.

POST-OPERATIVE TREATMENT

All patients who have had a spinal anæsthetic should be put

back to bed with the foot of the bed raised on blocks. Experience has shown that this is of greater value in preventing post-anæsthetic headache than any other factor. If the patient will tolerate this it should be maintained for at least twelve hours, and during this time he should avoid any raising of the head above the trunk. The two chief complications which may follow spinal anæsthesia are headache and retention of urine. There appears to be more than one form of headache but the usual kind is that which comes on a day or two after the operation and is experienced when the patient sits up or assumes the erect posture. It usually disappears when the patient lies down again. In duration it varies from a few hours to a week or more in severe cases. While it is present the patient should adopt a recumbent posture and drugs, such as aspirin or phenacetin and caffeine, may be administered. Retention of urine used to be a rather trying sequela of a spinal anæsthesia as it necessitated the passage of a catheter at intervals until normal micturition could be established. It has been found recently that the condition responds to the acetylcholine group of drugs and an injection of doryl will produce a fairly quick evacuation of the bladder. The injection can be repeated when necessary.

CONTRA-INDICATIONS TO SPINAL ANÆSTHESIA

As mentioned previously spinal anæsthesia should not be used for operations above the diaphragm unless the anæsthetist has had considerable experience in this type of work. It is unwise to use it in patients who are known to have a disease of their central nervous system. Even if the anæsthetic makes no difference to the course of the disease the patient may feel that it is to blame when any further symptoms occur. Patients who are *moribund* and *those in extremis* do not stand spinal anæsthetics well. The sudden drop in blood pressure is liable to act

as the last straw. The same thing applies to those who have lost a great deal of blood. On the other hand a patient who is suffering shock from painful stimuli as in a crushed leg may benefit greatly when the painful stimuli are cut off by the effect of the spinal anæsthetic. Unduly nervous patients are not suitable subjects for spinal anæsthesia unless they are made sleepy by adequate premedication or unless it is proposed to keep them asleep by means of a light general anæsthesia such as gas and oxygen. The extra stout patient may present some difficulty in the performance of the lumbar puncture and unless the anæsthetist feels that he is sufficiently skilled to undertake this it is probably better to adopt some other form of anæsthesia. Patients whose blood pressure is well below the normal and those who have a poorly compensated lesion of the heart are not very suitable subjects for spinal anæsthesia. Nor should it be given to patients who have sepsis in the region of the lumbar spine lest in doing the lumbar puncture infection should be carried inside the dura mater by the needle.

PROS AND CONS

The practitioner who proposes to use spinal anæsthesia would do well to consider the advantages and disadvantages of the method. Retention of urine is not such a drawback as formerly as it can be dealt with by doryl. Headache may be troublesome when it occurs but the number of patients who get it is only about 5 to 8 per cent. and this is little if any more than the percentage of those who get it after lumbar puncture for diagnostic purposes. Cases of permanent paralysis have been reported from time to time but these are rare and some of them at least appear to be due to faulty technique, such as making the puncture too high and injuring the cord. Ocular palsies are also very rare and fortunately these are always transient in

nature. The drop in blood pressure used to be considered a disadvantage and was at one time thought to be akin to shock. The two conditions are, however, different and while it is necessary to give intravenous fluid in shock it is not necessary in spinal anæsthesia because the normal amount of fluid is still there in the dilated vessels. As soon as anæsthesia passes off or vasoconstrictors, such as ephedrine are administered, the blood pressure rises again. Some surgeons welcome the fall in blood pressure as it enables them to work in a comparatively bloodless field and blood loss is reduced to a minimum. Of the advantages of spinal anæsthesia the one which probably appeals most to surgeons is the excellent muscular relaxation which is produced. This is invaluable for abdominal operations. Any surgeon who has had to put up with an unskilled anæsthetist or a difficult patient can testify to the advantages of having lax abdominal muscles to work with. Another advantage is that the operator can if necessary give the anæsthetic himself. A ship's surgeon or a medical missionary may have to operate with unskilled and unqualified assistants and to such a man a spinal anæsthetic is a great boon. Then, too, in a long and difficult operation it is a great advantage from the standpoint of the patient to have all painful stimuli blocked and prevented from reaching the brain. Spinal anæsthesia is also useful for patients who have disease of the chest and for whom the question of general anæsthesia may present a problem.

Many practitioners are a little scared of giving a spinal anæsthetic. Through lack of experience they may feel that they have lost control of the solution once it is inside the spinal canal and that there is always a possibility that the phrenic *nerves will become paralysed. Or possibly they have seen or* heard of bad results following the use of spinal anæsthetics

when given in unsuitable cases It is hoped that this brief account may perhaps clear up some of the points about this form of anæsthesia that are obscure to the practitioner who has to give anæsthetics as part of his day's work

CHAPTER VII

ANÆSTHESIA AND ANALGESIA IN MIDWIFERY

By JOHN ELAM, M.R.C.S., L.R.C.P.

CHAPTER VII

ANÆSTHESIA AND ANALGESIA IN MIDWIFERY

ANÆSTHETICS are administered in midwifery for two purposes: (1) for some operative interference; (2) to relieve the pains of labour.

IN OPERATIVE MIDWIFERY

For general anæsthesia in operative midwifery the safest and most satisfactory anæsthetic is nitrous oxide and oxygen with the addition of ether as required, and the general practitioner requires simplicity in technique of administration and of apparatus for use in private houses or in nursing homes. To administer gas-oxygen-ether there is no need for expensive or weighty machinery. A cheap metal stand is required to hold one nitrous oxide and one oxygen cylinder and small twin Boyle's bottles. Each cylinder is fitted with a screw-type pressure reducing valve. To the Boyle's bottles are attached rubber tubing, gas bag, three-way stop-cock and face-piece. A Clausen's harness and Hewitt's airway are also

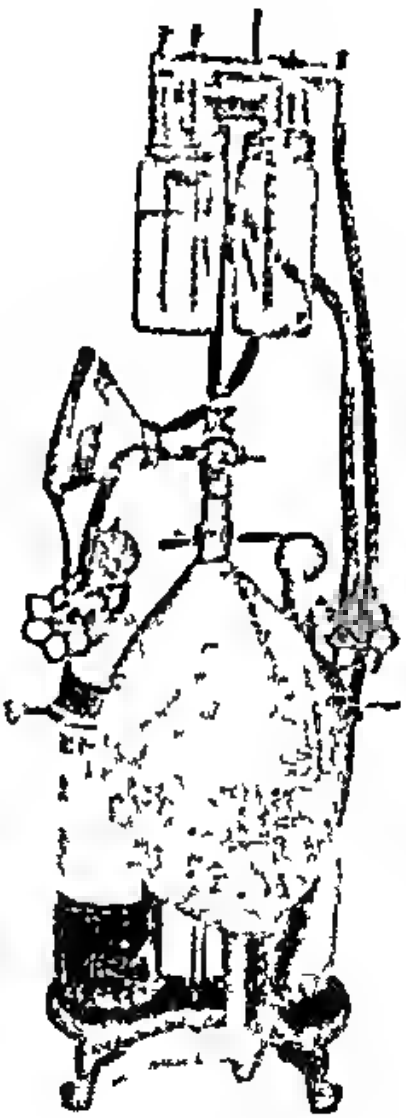

FIG 7.—A simple portable Boyle's apparatus for gas oxygen ether anæsthesia and gas oxygen analgesia

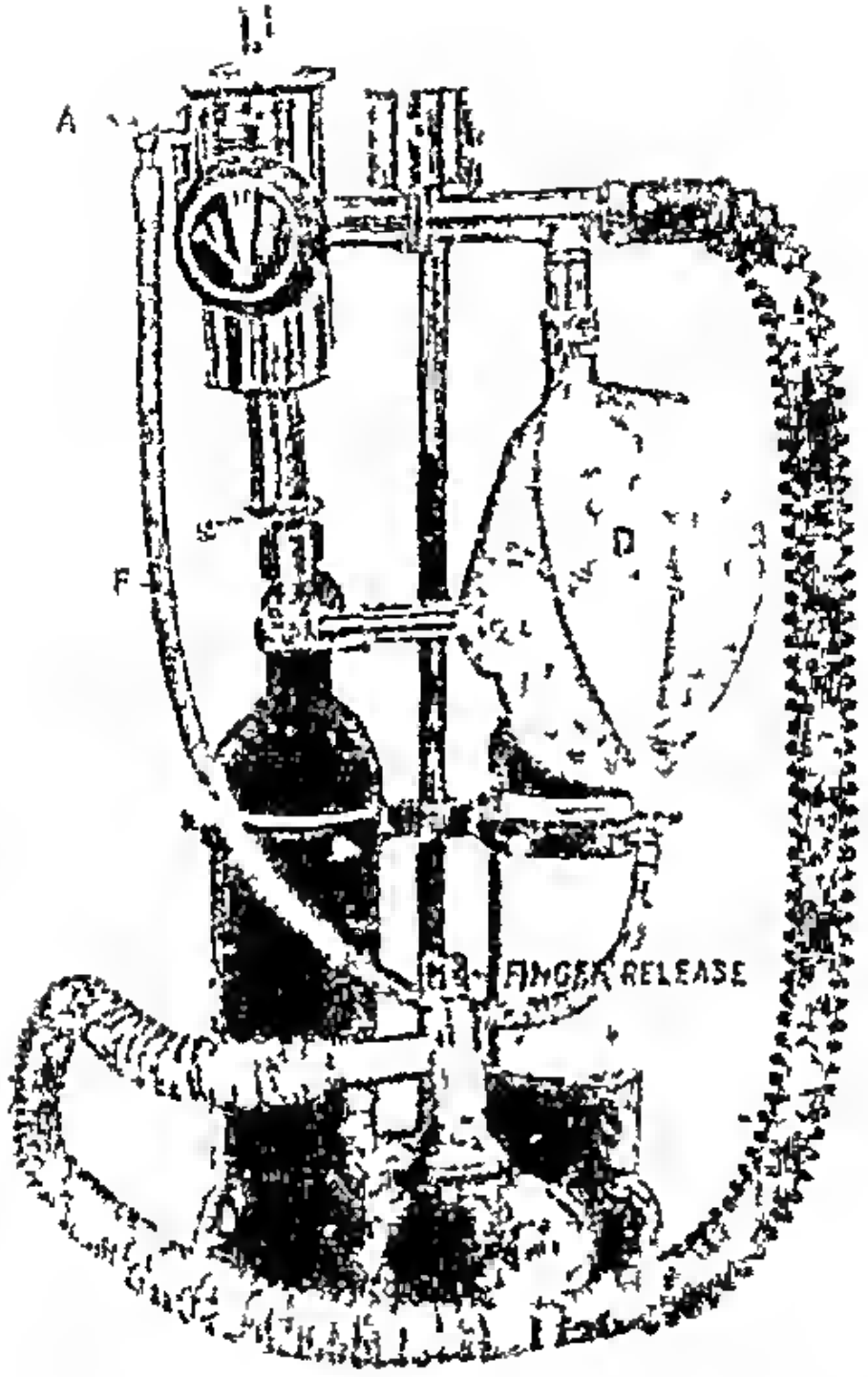

FIG 4 —A new (and at present experimental) apparatus for the administration of gas—gas and air analgesia

Gas flows from the gas cylinder to the low pressure chamber B where the pressure is reduced to 8–10 ounces to the square inch

At the top right hand corner of the low pressure chamber is a pilot jet A, through which gas flows into the bag D the rate of flow being about 1 gallon of gas every two minutes When the gas bag is full the pressure rises to 8–10 ounces to the square inch, the same as that in the low pressure chamber and the flow of gas is stopped The flow of gas is controlled by a spring release valve on the facepiece E. When the patient inhales, the bag is emptied by the first two breaths, and then gas is drawn direct from the low pressure chamber B through the carburettor C where it is mixed with air Thus we have administered gas—gas and air analgesia

necessary. Such an apparatus can be purchased for approximately £10.

A new low-pressure reducing valve* has recently been produced by the Dental Manufacturing Company and if this is fitted to the nitrous oxide cylinder it can be used both with the Boyle's bottles for nitrous oxide-oxygen anæsthesia and for self-administered gas and air analgesia by fitting an intermittent flow apparatus such as the Dental Manufacturing Company's gas and air carburettor.

If the practitioner has to apply forceps, he anæsthetizes his patient with gas-oxygen-ether sequence, when an airway can be inserted and the face-piece firmly held to the patient's face by means of Clausen's harness. The ether is turned off and the anæsthetic continued by means of nitrous oxide and oxygen. Should the practitioner be working without an anæsthetist, a nurse or midwife can be told to watch the bubbles coming through the two tubes in the sight feed bottle, and if the delivery is longer than was expected, can easily turn on the ether and deepen or prolong the anæsthesia. If the gas-oxygen-ether technique is not acceptable, ethyl-chloride-ether sequence will be found safe and satisfactory. Ethyl chloride is sprayed on to an open mask until the patient is anæsthetized and the anæsthetic is then continued with open ether. Open ether is a safe anæsthetic, and after the induction period the administration can usually be trusted to a nurse working under supervision. If chloroform must be used, it is safer to avoid the open mask and drop-bottle administration and to make use of some form of Junker's inhaler. The induction should always be in charge of the medical practitioner, but a nurse may be trusted to maintain the anæsthesia.

*The reducing valve is shown on Fig 4, where it is part of a new gas—gas and air machine.

A new anæsthetic, vinesthene (May and Baker), has recently been introduced which has proved of great value in operative midwifery as it is extremely easy to administer, is rapid in action, has little effect on the uterine muscle, causes little or no vomiting and its effects pass off with quite remarkable rapidity. Vinesthene is sold in glass ampoules containing 3 c.cm. or in sealed bottles containing 25 c.cm. For a short anæsthetic 6 c.cm. can be placed in a Clover's inhaler. The face-piece of the inhaler is applied to the patient's face and the barrel of the inhaler turned to 2. In a few breaths the patient is anæsthetized with relaxation sufficient for a minor operation. The anæsthetic can be continued by giving one breath of air to four breaths of vinesthene in the Clover and the 6 c cm. of the vinesthene will last about ten to twelve minutes. It is, however, in the operation for Cæsarian section that I have found vinesthene so particularly useful. The operation may take perhaps half-an-hour and the 6 c.cm. in the Clover's inhaler will not suffice. I have found that by placing 25 c.cm. vinesthene in the small (chloroform) size Boyle's bottle and blowing gas and oxygen over this, an anæsthetic giving adequate relaxation can be obtained and can be maintained for half-an-hour.

On one or two occasions I have added ether just before the peritoneum was closed, as the surgeon did not appear to be quite contented, but I have found passing the mixed gases over ether for twenty breaths quite sufficient.

IN NORMAL LABOUR

A more difficult problem is the relief of the pains of labour in the large number of confinements conducted by midwives in homes without the presence of a medical practitioner. Moreover, a high proportion of women go to municipal maternity hospitals (in 1936 there were 18,000 confinements in the

London County Council hospitals), where, as a rule, anæsthetists are not provided to attend normal confinements. Again, most patients who are attended by general practitioners cannot afford to pay for an obstetrical anæsthetist. In these cases, for the ideal method must be substituted one that is practical and safe.

Labour may be divided into two stages: the first, when the pains are not severe and the second stage when they are severe and frequent. For primiparæ this second stage starts shortly before full dilatation of the cervix, and for multiparæ at about dilatation of the cervix to the size of a five shilling piece. I do not think that any inhalation anæsthetics are really suitable in the first stage of labour and reliance must be placed on some sedative drug.

DRUGS IN FIRST STAGE

The requirements are: (1) The drug should give prolonged analgesia with the minimum possible of repeated doses (Reynolds, 1934). (2) The patient should sleep between the pains, but should rouse during them. (3) Labour should not be prolonged. (4) The child should suffer no ill-effects from absorption of the drugs used. Sedative drugs used are potassium bromide and chloral mixture, morphine, morphine and hyoscine, avertin, paraldehyde, nembutal, sodium soneryl, and, more recently, pentothal.

(A) *Potassium-bromide-chloral.*—These are usually given with an initial dose of 30 grains of each, repeated in similar doses at three and four hourly intervals. The analgesic action of these drugs is not of great value, but their sedative action is of value.

(B) *Morphine.*—Morphine is the most valuable sedative drug for use during labour and is probably the safest. Morphine should be given early in labour by injection in a dose of

¼ grain for primiparæ when the cervix is dilated to admit two fingers and for multiparæ when the cervix will admit one finger. Prof. Louise McIlroy and Dr. Helen Rodway (1933) found that contrary to the belief of many obstetricians, morphine had no ill-effect on the infant, but that spontaneous respiration occurred at birth in the majority of cases however late morphine was administered. Messrs. Hoffman–La Roche prepare extremely convenient leaden ampoules of morphine—¼ grain fitted with a hypodermic needle covered with a glass cap ready for use. To give a hypodermic injection of morphine, all that is necessary is to remove a small lead strip, press the glass capsule downwards, thus unsealing the ampoule, and then inject the needle under the skin and press the leaden capsule.

(C) *Paraldehyde* given per rectum dissolved in olive oil with a dosage of 60 minims per stone body weight with a maximum dose of one ounce has been recommended by some observers, but this drug, when tested by the British College of Obstetricians and Gynæcologists, did not meet with approval.

(D) *Morphine and hyoscine.*—Morphine ¼ grain, with hyoscine 1/150 grain, is given early in labour. Afterwards, hyoscine 1/450 grain is given at intervals of from two to four hours, depending on the patient's reaction Morphine-hyoscine is not a very suitable sedative for the majority of domiciliary maternity cases. Good results, however, can frequently be obtained from a single injection of hyoscine compound A early in labour: (hyoscine hydrobrom. 1/100 grain, morphine sulphate 1/6 grain, atropine sulphate 1/180 grain.)

(E) *Avertin, nembutal, sodium soneryl* and other basal narcotics have been found extremely useful for premedication in general surgery, and their use in midwifery has been advocated by some workers. Success can often be obtained by a single dose

of sodium soneryl given early in labour. Five capsules are given by mouth as soon as the pain becomes unpleasant. The drug must be administered before the pain becomes severe or it is of little avail.

In the case of sedative drugs two questions arise: Are they absolutely safe? Can they be given in everyday midwifery? The answer is "no," with the exception of potassium-bromide-chloral and morphine. Here must be considered the average maternity case, not the wealthy patient who engages an experienced professional anæsthetist to relieve her of pain. Many observers have published satisfactory series of cases in which pain has been relieved by powerful sedative drugs, but until some authoritative large-scale investigation as to their safety is carried out, these should be restricted to hospital midwifery and the practice of the experienced anæsthetist. Recently for example, Mallinson (1938), published a successful series of cases given nembutal-chloral narcosis throughout labour. No untoward effects were noticed but he gives a warning that this method should not be used in cases of toxæmia pregnancy or for what he calls "chesty patients." In fact, excellent though the nembutal-chloral technique may be it is applicable only to selected cases.

IN THE SECOND STAGE

We now come to the second stage of labour in which an inhalation anæsthetic is suitable. For much of the present knowledge of inhalation methods of relieving pain in labour we are indebted to Lady Baldwin and Lady (Rhys) Williams and their friends in the National Birthday Trust Fund, who, by their unremitting efforts over a number of years have at last brought safe and practical methods of alleviating pain. For inhalation agents we are confined to chloroform and nitrous

oxide gas. Other drugs have been used, but all have disadvantages which cannot be overcome in everyday midwifery.

Chloroform.—Chloroform capsules provide an easily portable and satisfactory method of relieving pain in a large number of cases. To avoid possible dangers from an overdose with capsules, Mennell has produced a modified Junker's inhaler from which the patient cannot obtain an overdose and which cannot be upset or spilt. Another ingenious inhaler has been produced by Christie Brown. Satisfactory results can be obtained from the use of Junker's Inhaler and the patient can herself administer the analgesia. The bottle of the inhaler can be hung on the top of the bed and the patient is given the bellows and mask and told to compress the bellows and inhale from the mask when pain is coming. Young Simpson has produced a special face-piece fitted with an air intake controlled by an automatic valve, and this face-piece can be used in conjunction with a Woulfe's bottle for self-administration of chloroform and nitrous oxide.

Now chloroform is cheap, is easily portable, and the administration requires no special skill. The important question remains: is it absolutely safe? The answer to this question is given by the British College of Obstetricians and Gynæcologists who have carried out a comprehensive test of various methods to obtain relief from pain. They have regretfully come to the conclusion, that there is no way in which chloroform can be made reasonably safe for producing obstetrical analgesia for that large number of women attended by midwives. This test carried out by the College was exceedingly thorough and painstaking, and after the conclusion come to by the College it is evident that there is no justification for using chloroform in everyday domiciliary midwifery.

Nitrous oxide.—The ideal for midwifery is unquestionably a

mixture of nitrous oxide and oxygen, and, I have already described a small portable Boyle's machine which can be used for general anæsthesia and analgesia. To obtain analgesia from gas and oxygen about 80 per cent. nitrous oxide and 20 per cent. oxygen is administered. When it is decided to start the administration, the patient is given the face-piece of the apparatus and told to apply this to her face when pain is coming, and it will be found of advantage if a length of corrugated rubber tubing is placed between the gas bag and the face-piece so as to avoid the gas bag being damaged. A two-gallon bag is filled with pure gas and the stop-cock turned to "air." When the pain comes the patient puts the face-piece on her face and inhales deeply from the bag. Immediately she does this the stop-cock is moved to half-way between "valves" and "full-rebreathing." The gas and oxygen are turned on, running in the proportion of one hole oxygen and four holes of gas through the sight-feed. This mixture is inhaled by the patient while the pain lasts. The face-piece is laid on one side when the pain goes away. While the patient is resting between the pains the stop-cock is turned back to "air" and the bag allowed to fill once more with pure gas. This technique is continued until the head is "crowned," when continuous gas and oxygen are administered. Care should be taken not to give too much gas, otherwise excitation may ensue and the patient become troublesome. She should not be allowed to go "right off" until the baby is being born.

There are automatic nitrous oxide and oxygen machines obtainable which can be used for the self-administration of nitrous oxide and oxygen, but these machines are expensive and more within the province of the professional anæsthetist. The administration of nitrous-oxide-oxygen is not convenient in the vast majority of maternity cases, and we are greatly

indebted to Minnitt of Liverpool, who by his gas and air technique has solved most of the difficulties. The apparatus first used by Minnitt (1933) to administer gas and air was an adaptation of a McKesson oxygen-therapy apparatus and consisted of a reduced pressure regulator combined with a small rubber bag enclosed in a metal drum so arranged that an automatic valve prevented the flow of gas when the patient did not inhale. The outlet of the machine was divided into two channels, one for the passage of gas and the other for air admitted in a constant amount, making a mixture approximately 45 per cent. nitrous oxide in air. The low percentage of nitrous oxide prevents the patient ever becoming fully anæsthetized, but she experiences a numbness and a sense of well-being. Minnitt's method has been carefully investigated and his gas and air technique is now generally adopted.

At the Wellhouse Hospital, Barnet, we have administered gas and air analgesia to all maternity patients since November, 1933, and are well satisfied with the results obtained. These results can be judged from an analysis of 1,500 cases. I believe that the amount of success obtained from gas and air analgesia is directly proportional to the amount of trouble taken over the administration I regard the technique of administration as extremely important, and attention must be paid to small details. The apparatus must be in order, the cylinders must contain gas and the gas must be turned on.

AN ANALYSIS OF 1,500 MATERNITY CASES GIVEN GAS AND AIR ANALGESIA AT THE WELLHOUSE HOSPITAL, BARNET

Total number of cases receiving gas and air analgesia	1,500
Primiparæ	880
Multiparæ	620
Primiparæ experienced *no pain* after gas and air was started	541
Primiparæ found *great relief* after gas and air was started	331
Primiparæ *disappointed* after gas and air was started	8

Multiparæ experienced *no pain* after gas and air was started -	332
Multiparæ found *great relief* after gas and air was started - -	280
Multiparæ *disappointed* after gas and air was started - - -	8
TOTAL - - - - - - - - - -	1,500

Forceps delivered under general anæsthesia - - - -			74
Stillbirths - - - - - - - - - -			44
Breech cases delivered under gas and air - - - -			36
Maternal death due to post-partum hæmorrhage following forceps delivery and manual removal of placenta - -			1
Total cost of gas for 1,500 cases -	£187	10*s.*	0*d.*
Cost per case - - - -		2*s.*	6*d*

It is quite easy to continue the administration with empty cylinders. From the sound which the machine makes it is difficult to tell whether or not gas is flowing, but a pressure gauge is usually fitted which shows that the gas is flowing. Care should be taken to explain to the patient before the administration starts exactly what to expect. She must be told that she will not lose all sense of feeling. She must be persuaded to co-operate and hence the importance of not making the patient too sleepy with sedative drugs in the early stages of labour. The patient alone can tell when pain is coming, and as the gas has to win a race with the pain, she must be told to inhale the gas immediately she feels the pain is coming, and must continue to breathe in and out through the face-piece while the pain lasts, and for a few breaths afterwards.

The face-piece is an important item and care must be taken to see that this is comfortable, is an accurate fit, and that the patient knows how to apply it to her face. Sometimes the patient will not hold it on her face, saying she has not the strength to do so, sometimes she may throw it on the floor. In either of these two events, a little firmness is necessary. If the face-piece is thrown on the floor it should be left on the floor

until the patient has had the experience of a really good pain, when it will be found that she will loudly demand the return of her comforter and will not again be separated from it.

Some patients are so fond of the gas that they attempt to give themselves continuous gas and air and will not lay the face-piece on one side between the pains. In such an event the attendant should not engage in an undignified struggle with his patient, but should pinch the tube so that a vacuum will be created and the patient will have to lay the face-piece down. Sometimes a woman is met with who thinks she must blow into the face-piece only, and not inhale from it, but a little patience and tact will overcome these difficulties. When the pushing-down stage is reached, the patient must understand that it is necessary for her to inhale the gas before pushing down. She must take several breaths of gas, hold her breath, and then push down, more breaths and then push again.

When delivery is about to take place continuous administration should be given, and here it is an advantage if the attendant, a nurse or female relation, will hold the face-piece on the patient's face. Some observers do not consider that gas and air is sufficient for the actual delivery and administer a little ether or chloroform. There is no reason why this should not be done, although I do not consider it is necessary.

The chief disadvantage is that a fixed percentage of nitrous oxide in air is administered, and as all women do not respond equally to the inhalation of nitrous oxide, it is obvious that the less susceptible patient will not be so satisfied as her more fortunate sister. This can be overcome by increasing the percentage of nitrous oxide in air, and machines are now obtainable from which any desired percentage of nitrous oxide in air can be obtained. Chassar Moir (1937) goes further and

advocates two to three breaths of pure gas with each pain, and for this purpose has produced an automatic apparatus from which the patient obtains a limited supply of gas (110 ounces) from an automatically operated gas-bag which fills slowly and empties quickly, thus preventing an overdose of gas. Anæsthetists are not yet agreed as to the suitability of this technique for domiciliary midwifery. Further work is necessary before we can decide if Moir's method is more satisfactory than that of R. J. Minnitt. The objection is, that after the 110 ounces of gas are used up, no more gas is available until the bag is filled again, which takes one minute, so that during a long pain the effect of the gas has worn off before the pain passes away.

The most satisfactory solution would be to give two breaths of pure gas, followed by gas and air, and a machine has recently been produced for this purpose and has given good results at the Wellhouse Hospital, Barnet (fig. 4). Sufficient work has not yet been done to give a definite opinion as to the safety of this method, but it may well be that more satisfactory analgesia will result from its use, and that the failures which at present have to be expected from gas and air analgesia may be eliminated.

The Central Midwives Board have ruled that any apparatus to be used by midwives must not be capable of giving more than 45 per cent. of nitrous oxide in air, but my experience is that a higher percentage can be given with advantage and with absolute safety. I find 60 per cent. nitrous oxide satisfactory.

An objection to Minnitt's method is that the apparatus is rather costly and gas cylinders are heavy things to carry about. With a little organization however, there should be no need whatever for midwives or practitioners to carry gas cylinders

at all The manufacturers of nitrous oxide gas give extremely good service and will deliver on hire any number of gas cylinders required, so that these cylinders could be delivered at some central point in each district, say a district nursing institute, from where they could be collected by the patients' relations a few days before the confinement is due and to be

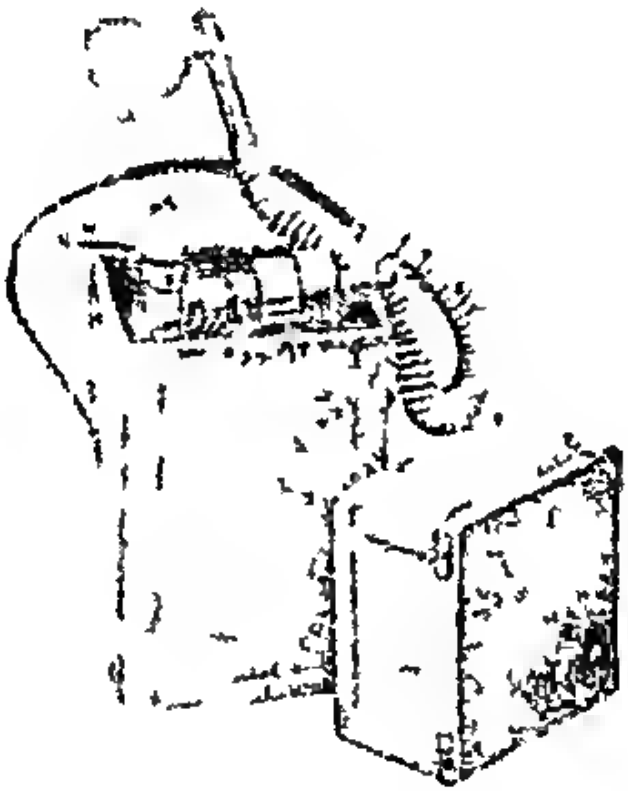

Fig 5 —The Walton Minitt apparatus

ready for use in the house when required

Two new machines have recently been produced, one by Messrs A Charles King and one by the British Oxygen Company The former have produced a very small light machine fitted into a fibre box The British Oxygen Company have made a small portable apparatus fitted into a very convenient case and holding only one 50 gallon cylinder instead

of the usual two 100-gallon Special attention has been paid to the ease and quickness of changing cylinders, so that not a moment may be lost when a cylinder is empty before a new one is fitted

The British College of Obstetricians and Gynæcologists have carried out a careful test of nitrous oxide and air administered

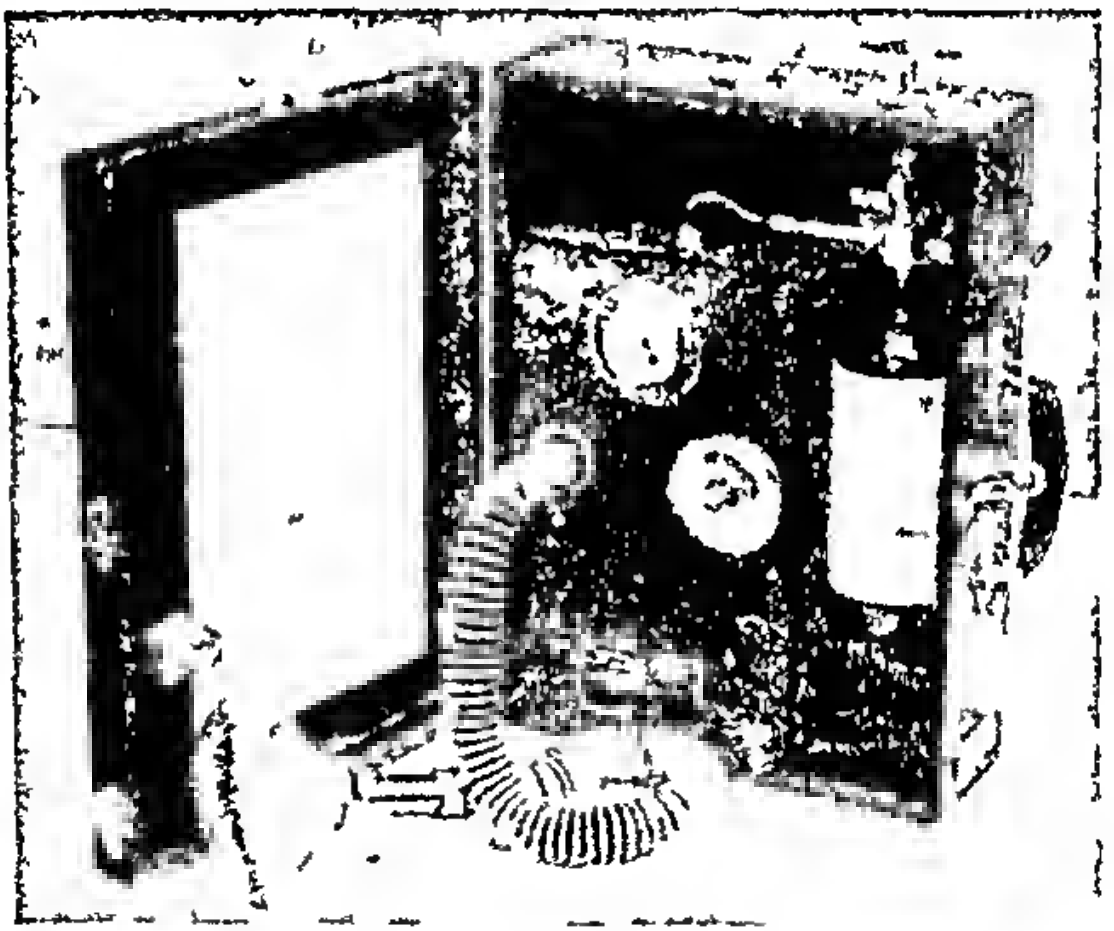

Fig 6.—Queen Charlotte's gas air apparatus

by the Minnitt apparatus and have come to the conclusion *that gas and air so administered does not increase the risk* of death in childbirth, and that the method does not involve any added risk to the fœtus, and that the actual administration does not call for any more special skill than that which may be required by a midwife during her period of training

They found, too, that there was no remote risk to the baby, and no deterrent influence on the natural course of labour when analgesia was administered by the patient herself. The Central Midwives Board have now altered their regulations and have decided that with certain safeguards a midwife may administer gas and air to her own patients.

Gas and air analgesia will not suffice for forceps delivery, but is satisfactory for the insertion of one or two stitches into the perineum. For this purpose twenty breaths of gas and air are given before the stitches are inserted, and the administration is continued throughout the operation.

We now have satisfactory means of relieving the pains in the second stage of labour. Owing to Minnitt's invention the midwife's case can be given gas and air. For the case attended by the general practitioner gas and air will generally suffice, but the practitioner who wishes, and undertakes to give, absolute relief from pain must use nitrous oxide and oxygen in a small percentage of cases. The very nervous patient, the very heavy patient, and the patient who has had previous experience of a forceps delivery under general anæsthesia, or the patient who has received a skilfully administered chloroform analgesia may not be altogether satisfied with gas and air, and to the few patients who come under these headings, gas and oxygen may be administered. The adoption of gas and air analgesia will be of as great benefit to the busy general practitioner as it is to his patient. In most cases he will not be obliged to spend many hours at the bedside of his patient and by those of us who are not enthusiastic nocturnal obstetricians this relief will be appreciated.

We may as well face the fact, that no really satisfactory sedative drug has yet been found to relieve pain in the first stage of labour. Morphine is the safest and the most reliable.

CONCLUSIONS

I have discussed the question of relief of pain in labour at some length, but all I have to say may be summed up in a few words. Morphine early in labour, gas and air analgesia in the second stage of labour and gas and oxygen analgesia for that small percentage of patients who do not respond to gas and air.

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CHAPTER VIII

ANÆSTHESIA AND THE CHILD

By FRANKIS EVANS, M.B., B.S., D.A.

CHAPTER VIII

ANÆSTHESIA AND THE CHILD

THE administration of anæsthetic to a child requires tact and a sympathetic understanding, for the child, the parent, and the surgeon must each be given due consideration. The surgeon requires a patient adequately and safely anæsthetized with a minimum of fuss and bother, and with the least possible after-effects. It is also important from his standpoint that the anæsthetist shall please the parents and impress them favourably. No parent can contemplate surgical interference in respect of his or her offspring entirely unmoved, and it should be the anæsthetist's best endeavour not only to reassure the parents but also to co-operate with them as far as possible and to induce them to co-operate with him as well A mother should always be allowed to remain in the picture for it is the greatest mistake to give her the impression that her child is being taken out of her charge and control, and that she no longer has any helping hand in its well-being. A kindly smile and a reassuring word go a long way with a worried mother and if she sees that the anæsthetist and her child understand one another all will be well. Children readily sense an atmosphere and are quick to realize parental distress! Hence the anæsthetist's work begins with a combined interview with mother and child, reassuring the one and gaining the confidence of the other.

With regard to the patient, first the age will be considered;

secondly, the nature of the operation and general condition of the patient and, lastly, the method of approach, which is all important. To consider this last point first, it must be borne in mind that children are very observant with memory that begins to function early in life. Even two-year olds sometimes remember outstanding events, as witness their reactions when the same set of circumstances is repeated. It is therefore of the utmost importance that the anæsthetic shall be so administered that the child shall have no unpleasant memories or fear afterwards. Too much stress cannot be made of this point, for many patients have been encountered who have had distressing experiences whilst being anæsthetized. It is easy to render a patient unconscious, but skill and understanding are required to do it pleasantly from the patient's point of view. Many patients volunteer the information that they have horrible childhood memories of being carried into an operating theatre by a white-robed nurse, and of being held down whilst a suffocating vapour was poured over a mask applied to the face. Then followed a struggle for breath, an attempt to tear away the mask, an increase in the suffocating vapour, a few more gasping breaths and then unconsciousness. Children do not forget that sort of experience and nightmares of a suffocating type may persist for some months afterwards. Modern methods have changed all this Comfortable anæsthesia can be achieved in two ways, (1) by adequate premedication (see page 152), and (2) by sound choice of the anæsthetic agent and its method of administration. The induction is all important and, as most people resent a mask being placed firmly over the nose and mouth, the most satisfactory method of inducing anæsthesia is by means of nitrous oxide administered in large volume through a mask held at least two inches from the face. It is not an economical method, but it gives a smooth slipping

off into unconsciousness and earns the lasting gratitude of the patient. The full technique of this is discussed below.

CONSIDERATIONS OF AGE

The age of the patient must be considered, especially in consideration of premedication, and for this purpose it is convenient to group children arbitrarily into four groups. These, of course, overlap considerably, for a child of two years may be large or small for its age, sharp or dull, biddable or suspicious Below are given the four arbitrary groups, but this must not be too literally interpreted.

Birth to 20–24 months.
2–5 years.
5–12 years.
12–16 years.

In the first group, the babies, are patients who will not carry any memory of this period into later life so that premedication is both unnecessary and inadvisable. The "two-year-olds," however, frequently remember outstanding events and it is in this group that premedication must be considered. It is not possible to reason with the very young and to explain to them the reason of things. It is much simpler to administer some suitable soporific premedication so that the child knows nothing and is frequently unaware of having had any surgical procedure. It is sometimes necessary to make some sort of explanation for changed routine, to avoid any growing suspicion, which leads to a refusal to swallow the necessary drug. Given a sensible mother, and a good experienced nurse, the practitioner's difficulties are halved.

The third and fourth groups (5–12 years and 12–16 years)

present an easier problem, for the children are usually aware that an operation is to be performed, and when matters are explained to them are willing to co-operate.

PREMEDICATION

Premedication (except in the case of babies and in certain special circumstances) is both safe and desirable. There are several drugs which can be used, and there are several avenues by which they may be administered. On the whole the barbiturates have pride of place, for they are safe and easily administered, though avertin (tribrom-ethyl-alcohol) and paraldehyde have their advocates. These latter are administered per rectum and therein lies their drawback. Every small child resents a catheter being passed into the rectum and tends to expel the injected fluid unless it has been run in with extreme care. Irritation of the rectal mucosa has been mentioned as occurring after the administration of drugs by the rectal route, but I have not experienced this. Premedicatives should be adequate and not be too much or too little. Failure or uncertain results may be due to several causes. Capsules given by mouth have been known to be "parked" in the side of the mouth and spat out under the bed when the nurse was not looking. Food in the stomach delays absorption, as does omitting to prick the ends of the capsule before swallowing. Fæces in the rectum also delay and prevent absorption of drugs given per rectum. Below is given a suggestion for suitable premedication at various ages.

It is inadvisable to give any soporific premedication below two years of age as a rule, and the only pre-operative drug recommended is a hypodermic injection of atropine, $\frac{1}{100}$ grain, to control salivation.

TWO TO FIVE YEARS OLD.—Children need some form of premedication which is easily assimilable and can be swallowed. The rectal route is not too easy at this age.

Nembutal is a barbiturate well tolerated by children and is given orally in a little jam or honey together with the requisite dose of atropine ($\frac{1}{75}$ grain by mouth). A little honey is placed in a teaspoon and the powder sprinkled on the top of this. The powder is itself covered with more honey, thus forming a sandwich. A skilful nurse puts this into the child's mouth quickly and the honey mixture is swallowed. The nembutal should be given one hour before operation, and there are some practitioners who recommend the addition of 30 minims of milk of magnesia to hasten its absorption. Apprehension will interfere with gastric function, and occasionally a child will vomit undigested food which was taken nearly twenty-four hours previously. Fortunately this does not happen frequently, but it should be remembered because it interferes with the absorption of nembutal. After the drug has been swallowed the blinds should be drawn and the child prepared for sleep if possible. It is inadvisable to move the child from a warm cot and carry it into another room because this will tend to rouse it. The child should be anæsthetized in its bed.

The oral dosage of nembutal recommended is as follows:—

Age 2 years—1–1·5 grains.
„ 3 years—1·5 grains.
„ 4 years—1·5–2 grains.
„ 5 years—2 grains.

Another method of estimating dosage is to give 0·6 grain per stone of body weight.

Rectal nembutal is recommended by Jarman (1936) for small children, but I have not tried this method.

AGED FIVE TO TWELVE.—The child can quite easily swallow a capsule containing the required dose of nembutal, thus avoiding its bitter taste. It is well to administer a little milk

of magnesia at the same time to aid absorption and also to pierce the ends of the capsule with a fine needle

Avertin may be used per rectum instead of oral nembutal for these children and is quite safe in the recommended dose of 0·1 gramme per kilogramme of body weight There has been some reluctance to use it in this dosage with children, but my experience is to the effect that this dosage tends to be on the small side The only drawback to its use is psychological, children resenting anything being passed into the anal canal (*see p 152*) The avertin is prepared in a 2 5 per cent solution The avertin fluid is added to warm distilled water and well shaken, and to this is added 5 drops of 1 in 1,000 congo red The resultant solution should be faintly pink Should the colour change to blue the presence of acid is indicated, showing that the avertin has broken up and become irritant to the rectal mucosa The warm avertin solution is run into the rectum slowly, with the patient on the right side, buttocks raised An enema may be given the night before, but not on the morning of operation, for it only worries the child and irritates the rectum if this is done just before the avertin is to be given

From the age of twelve years children are usually very sensitive and for this reason the rectally administered drugs are not advisable *Intravenous evipan* is well tolerated although there are some practitioners who criticize the administration of any drug by the intravenous route They argue that once the drug is in circulation it cannot be got out again But given by a careful administrator it is as safe, if not safer, than a drug given per rectum or by mouth

The evipan injection is preceded by a hypodermic of omnopon $\frac{1}{6}$ to $\frac{1}{3}$ grain in the case of older children, some thirty minutes beforehand This renders the prick of the evipan needle practically painless and definitely diminishes the subse-

quent quantity of evipan required. One gramme of the evipan is dissolved in 10 c.cm. of distilled water, 1 c.cm. of this is injected slowly into a vein in the antecubital fossa and its effect noted. After a pause of some thirty seconds a further 1 c.cm. is injected. The patient, who has been instructed to count out loud, usually becomes muddled after 3 c.cm. and begins to snore. No further evipan need be injected, and the anæsthetic may be administered immediately. In passing it may be noted that Vann Bros. make an excellent evipan needle, which has a short bevel and fine bore and is excellent for use with an eccentric nozzle syringe. It is well to keep one finger on the skin at the point of entry of the needle, for if the tourniquet be released roughly the needle may be jerked out of the vein. It should scarcely be necessary to remind the anæsthetist to see that the tourniquet is completely released before injection is begun. It is possible to distend the vein with the drug before releasing the tourniquet, which may produce serious consequences.

METHODS OF ANÆSTHESIA AVAILABLE

The methods of anæsthesia available are (1) general, (2) local, (3) spinal.

Local anæsthesia (0·5 per cent. novocain) is used by some surgeons for babies when operating for hypertropbic pyloric stenosis.

Spinal anæsthesia has been used by W. E. Wilson with success for the same condition. He explains in a private communication that he has used an intrathecal injection of 2 c.cm. of *1 in 2,500 percaine light solution. The injection is made by* means of a no. 18 bypodermic needle with the baby held sitting up. The puncture is made in the fourth space, and the fluid is injected warm at 105° F. Fifteen to twenty seconds

after the injection the child is placed in a 45° Trendelenburg position. This gives anæsthesia to the nipple line. Wilson states that he has so far had no fatalities but wishes to obtain a larger number of cases before being really dogmatic. The youngest child in his series was seventeen days and the oldest four months He says that his results are most encouraging and that the patients lie apparently sleeping and show no suggestion of distress, and, although the blood pressure has not been recorded, there appears to be no evidence of a fall.

General anæsthesia may be divided into open and closed methods, and of the open methods the "A.C.E.-ether" sequence, ethyl-chloride-ether sequence, vinesthene, and chloroform stand out. "A.C.E" dropped on a Bart's lint by means of a Mills' drop-bottle is a safe, if slow method of induction. Starting with one "shake" gradually increasing to four shakes, and turning the lint after each series of "shakes," is the technique for anæsthetizing a baby. As soon as anæsthesia is complete continue with ether dropped on a Bellamy Gardner wire mask covered with house flannel or gauze.

"A.C.E." may be dropped on to a mask from the beginning, but this method tends to rapid overdosage unless there is a big air space under the mask.

Ethyl-chloride-ether though widely used is not without risk. The ethyl chloride should be dripped on to the mask as slowly as possible and when regular breathing supervenes a gradual change to ether is made. The danger signs of ethyl chloride are a dilated pupil and laryngeal stridor. In both cases the mask should be removed until the disturbance has passed.

Vinesthene (vinyl ether) is excellent for short operations, and the induction is rapid and smooth. It may be used by the open method in combination with an ether mask. The liquid is

dripped at about eighty drops per minute on to the mask, and anæsthesia is complete in some sixty seconds. Respiration is quieter than with ether and resembles that of chloroform anæsthesia. Recovery is rapid and there is little or no vomiting. Salivation may be troublesome, but can be controlled with atropine premedication. Vinesthene may be combined with nitrous oxide and oxygen in lieu of ether for short anæsthesias.

Chloroform as an anæsthesia has a definite place in the anæsthetist's armamentarium but it should *never* be administered to children. The child's liver is singularly susceptible to its toxic effects, and particularly so when the child has been what used to be called "properly prepared." It was the custom some few years ago to give the little hospital patient some meagre breakfast at 6 a.m., and then a little "essence" at 11 a.m. in preparation for an operating list beginning at 1.30 p.m. By this time the patient's blood-sugar was down to seriously low limits, and the liver being depleted of glycogen lacked its normal resistance and fell an easy prey to the toxic action of chloroform. The typical poisoning fortunately was rarely seen but minor degrees of toxicity often occurred as shown by vomiting and the excretion of large quantities of acetone bodies in the urine. Chloroform should only be used when there is laryngeal obstruction and then should be administered slowly. If the child is orthopnœic begin administering chloroform with the child sitting up. As soon as consciousness is lost the recumbent posture should be resumed. Chloroform may be given by means of a Mills' drop-bottle and a piece of lint.

The closed method as exemplified by nitrous-oxide-oxygen-ether may be administered even to tiny babies and is safe and easy to use. The only modification necessary is a much diminished rebreathing bag which should be about half the

size of a Magill bag. The induction should be begun with an oxygen flow of 1 to 1·5 litres (or two holes in the water sight-feed type of Boyle's machine) and a nitrous oxide flow of 4 to 5 litres (five holes with water sight-feed). As soon as the respiration becomes automatic ether is commenced and used in small quantities; for example it is seldom necessary to move the ether control lever further than the half-way (over the surface) position for such operations as circumcision. This form of anæsthesia is excellent too for *endotracheal insufflation*, but care must be taken when connecting the pipe line to the catheter; for if the vapour is too strong, its sudden flow into the baby's trachea may cause profound shock. Ether should always be cut off when first connecting up the apparatus to the endotracheal catheter.

PRE-OPERATIVE CARE

Feeding should be so arranged that there is ample store of glycogen in the body, for it is essential that the liver is protected with glucose against the toxic action of anæsthetic agents. It is therefore necessary to see that the child has added glucose in the form of barley sugar, "fruit drops" or lucosade (a lactose preparation and not so sweet) perferably for two or three days before operation. The last meal should be given some three hours before operation, and it is better not to give any milk as the clots formed in the stomach create danger if vomited. Sweet orange-juice to drink and a jelly, such as bramble jelly, which leaves no residue should be sufficient, with possibly a small piece of crustless bread and butter. The yolk of an egg may also be given, but not the white. This is adequate as a breakfast, but when the operation is delayed until the afternoon an ordinary breakfast may be given, followed at eleven by sweet orange juice and jelly to help the glucose reserve.

Some years ago whilst working on blood-sugar curves during anæsthesia I found that one child of ten years old whose operation was fixed for 1.30 p m. had a blood-sugar of 0.30 mgm. per cent.

The baby's operation should be arranged to take place some three hours after the last milk feed is finished, and the child should be given another feed as soon as it has come round from the anæsthetic.

Clothing should be warm and light, and if shock is anticipated the limbs should be bound with cotton-wool and a thick pad of wool arranged for the child to lie on while on the operating table. *Enemas* are best avoided unless there is a definite reason for their use.

CHOICE OF ANÆSTHETIC

No hard and fast rules can be laid down as to what anæsthetic shall be administered for any particular operation. Often it is a matter of personal prejudice, and it is always necessary to consider the general condition of the patient, toxic states, idiosynerasy, length of operation and likelihood of shock. However a list of the more common operations is given below together with suggested methods of anæsthesia. This is put forward merely as a suggestion and guide.

A. Baby.

(1) *Hare Lip.* Nitrous-oxide-oygen-ether endotracheal.
(2) *Circumcision.* Ditto.
(3) *Pyloric stenosis.* Ditto, or local.
(4) *Intussusception.* Ditto, or local.

B. Small Children.

(1) *Cleft palate.* Nitrous-oxide-oxygen-ether endotracheal.
(2) *Tonsil.* Ditto or ethyl-chloride-ether.
(3) *Appendix.* Ditto, or open method.
(4) *Mastoid.* Nitrous oxide-oxygen.
(5) *Myringotomy.* Ditto or vinesthene.
(6) *Empyema.* Ditto, ditto.
(7) *Bronchoscopy.* Intravenous evipan or pentothal.
(8) *Orthopædic.* Nitrous-oxide-oxygen-ether or vinesthene.
(9) *Tracheotomy.* Chloroform or local if not much swelling of the neck.
(10) *Dental.* Nasal nitrous-oxide-oxygen if biddable. If not, use ethyl chloride open.

I except in the case of nos 7 and 9 utilize the appropriate premedication

Dental operations can usually be performed under nitrous oxide in children from four years old provided they are reasonably good It is essential to keep the air valve on the nose piece fully open, and avoid pressure The signs of anæsthesia are (1) regular automatic breathing (stertor is a sign of *overdose*), (2) *slight cyanosis only*, (3) *fixed eye usually looking* down towards the feet The pupil should be small and not dilated Phonation is a sign that the patient is too deep

POST-OPERATIVE MANAGEMENT

Babies usually drop off to sleep if given a feed and firmly tucked up as soon as they are round from the anæsthetic Pain may be relieved quite satisfactorily by the use of a teaspoonful of port The late Harry Blakeway used this extensively after operation for hair-lip in babies with excellent results Nepenthe given hypodermically is favoured by some in a dosage of one minim per year with a maximum of five minims Aspirin may be given orally to children from eighteen months old, and the dose varies from a quarter of a tablet (1 25 grains) to half a tablet Orthopædic cases respond well to veramon, which does not cause sweating, for perspiration inside a plaster gives rise to irritation Veramon is eminently satisfactory for this purpose, as is also the Haustulus pot brom of the St Bartholomew's Hospital Pharmacopœia which is excellent Restlessness and excitement yield to a small dose of nepenthe or morphine if given quickly

SUMMARY

Adequate soporific premedication is desirable and safe in all children over two years old, but it is contra-indicated in severe toxic states, jaundice and dehydration The most satisfactory all round method of anæsthesia is nitrous oxide oxygen with a trace of superadded ether, and this method is eminently suited to the baby as well as to the older child

Reference

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CHAPTER IX

ANÆSTHESIA IN DENTISTRY

By T. B. VAILE, M.R.C.S., L.R.C.P.

CHAPTER IX

ANÆSTHESIA IN DENTISTRY

GENERAL anæsthesia is required by dental surgeons for two classes of patients, those requiring extractions which can be performed in the dental chair at the dental surgeon's consulting room, and those requiring the extraction of unerupted or badly-impacted wisdom teeth or other difficult and prolonged extractions, operations for dental cysts, alveolectomy, buried roots, and unerupted supernumerary teeth.

The majority of patients in the first group expect to be able to carry on their ordinary occupations shortly after the extractions and the dental surgeon expects a quick recovery and the patient to be able to leave at once. For this reason it will be found advisable not to extract more than six teeth of average difficulty or to give a longer period of anæsthesia than five minutes if possible, completing the work on another occasion if more is required. It was found at the Royal Dental Hospital before this was adopted as the usual routine that patients quite frequently complained of considerable tiredness and "feeling rotten" during the following day.

ORDINARY EXTRACTIONS

Anæsthetic.—The anæsthetic for these cases should be nitrous oxide and air or nitrous oxide and oxygen—the method of administration, nasal. The Karn-Jenkins nose-piece is an

excellent one and can be used either with the simple one-and-a-half-gallon gas bag connected to two cylinders of nitrous oxide on a foot stand or with a McKesson apparatus.

Preparation.—No special preparation is necessary and if the extractions can be arranged for 11.30 a.m. or after in the morning, or from 3.30 p.m. onwards in the afternoon, the patient should have an ordinary breakfast at any time up to 8.30 a.m. or a light lunch not later than 1 p.m. The ordinary morning evacuation of the bowels is sufficient and purging is undesirable. The bladder should be emptied just before the anæsthetic, so as to avoid urination during operation.

Administration.—The chair should be tilted slightly backwards to prevent the patient from slipping out of position. The patient, after loosening any tight clothing, should sit well back in the chair with the knees bent and feet resting on the base, and not against the end of the foot-piece of the chair. The back of the chair should be at right angles to the seat and the head-rest arranged to support the head comfortably and steadily so that when the mouth is open the floor of the mouth is parallel to the floor. In this position the tongue lies naturally in the floor of the mouth with little tendency to fall back. It may, however, be necessary to allow the head to be somewhat extended when wisdom teeth are to be extracted. The head should never be allowed to become flexed or respiration will be obstructed.

The dental prop should now be placed in position and, after air has been expelled from the apparatus, the nose-piece should be placed lightly in position and, after the patient has been instructed to breathe in and out through the nose, the administration started with a gentle flow of nitrous oxide and the expiratory valve on the nose-piece open. After one or

two breaths the nose-piece is pressed firmly on to the nose and the pressure at which the gas is administered increased. After sufficient time has been allowed for the escape of the nitrogen which was present in the air in the patient's respiratory system—which would otherwise dilute the nitrous oxide in the bag, the expiratory valve is closed to limit expiration, thus, by inducing rebreathing, both increasing the pressure of the administration and preventing "washing out" of carbon dioxide. Continue the administration until surgical anæsthesia, shown by regular automatic respiration, is established, allowing air when necessary (or adding oxygen until the correct percentage is obtained if nitrous oxide and oxygen is being used). The mouth is now packed with gauze or a sponge to which a tape is attached and the extractions begun, anæsthesia being maintained throughout through the nose, air (in the case of nitrous oxide and air) being admitted if and when necessary. The nose-piece must be kept tightly and accurately fitting throughout.

For a nasal administration of nitrous oxide to be successful too much importance cannot be attached to the maintenance of an unobstructed airway and, in addition to keeping the lower jaw well forward, care should be taken that the mouth pack does not interfere with the movements of the soft palate.

It will be found that a certain number of patients cannot be prevented from breathing through their mouths during the induction period. In these, the mouth-piece of the apparatus should be used in conjunction with the nose-piece until induction is complete and the mouth then tightly packed, after which it will be found that nasal respiration can be established, a slightly higher pressure being usually necessary than in other cases. During the operation should the anæsthesia become "light" and difficulty be experienced in

regaining control, the packing and any blood should be rapidly removed from the mouth and the mouth-piece applied until anæsthesia is again established. A portion of the packing can be placed on the operation area to control bleeding during this time, and the mouth then repacked and the operation proceed again.

The dental prop.—This should be made in one piece and not be wedged between the teeth, but should be of such a size that the patient has only to close the teeth slightly to grip it, otherwise it may be difficult to release it if necessary—if smaller, the prop may slip. If a prop of suitable size is not available, one should be placed somewhere in the mouth where it fits and a Mason's gag introduced and the prop withdrawn immediately induction is complete. If for any reason a prop cannot be inserted on the side opposite to the extractions, it should be placed on the side of the extractions and a Mason's gag introduced on the other side immediately after the mouth has been packed. A smaller prop placed far back in the mouth is usually better than a larger one further forward, especially when molar teeth are being extracted. A centrally placed prop is best avoided as it often interferes considerably with the proper control of the jaw. Care should also be taken not to place the prop on loose or weak teeth or porcelain crowns, otherwise these may be dislodged. The same applies to the use of the gag.

Special points.—Nitrous oxide can, if necessary, be administered nasally for a considerably longer time than has been recommended but, when this is done, arrangements should be made for the patient to rest at the dental surgeon's rooms for a time afterwards and then return home to rest. Of course, if unexpected difficulty with an extraction arises, the time recommended may have to be exceeded. The fact that this will

be possible enables the dental surgeon to work without haste and so avoid undue bruising and laceration of the tissues.

In addition to administration of the anæsthetic it is the duty of the anæsthetist to steady the patient's head and keep it in position for the dental surgeon, and also to accustom himself to using a Mason's gag quickly and gently as teeth often have to be extracted on both sides of the mouth. He has also to learn to place himself in such a position that he can see all that is being done without being in the way. The best position is for him to stand to the left side of the chair and very slightly behind it. Fragments of teeth and amalgam fillings often become loose in the mouth during extractions, and the anæsthetist should see that these are removed before the extractions proceed further.

DIFFICULTIES

Nitrous oxide and air has the following advantages over nitrous oxide and oxygen: (1) It is easier and simpler to administer. (2) It is less often followed by nausea. (3) Recovery is quicker. Nitrous oxide and oxygen on the other hand gives a smoother anæsthesia, and in children and anæmic patients is preferable on account of the lesser degree of suboxygenation.

Children under six years old are difficult to anæsthetize by the nasal method owing to the difficulty of obtaining an accurate fit of the nose-piece on their small noses, fear, and crying; if many extractions have to be performed, recent experience with divinyl ether by Goldman's method suggests that this is likely to prove a satisfactory alternative.

Difficulty may also be experienced with young athletic men, alcoholics, and in patients with nasal obstruction.

Dental extractions are often required as a preliminary before

surgical treatment of carcinoma of the tongue and floor of the mouth The readiness with which these growths bleed often makes these patients unsatisfactory subjects for nasal nitrous oxide, and I have found evipan or pentothal preceded by omnopon, ⅓ grain, and scopolamine, 1/150 grain, satisfactory in these cases—the number of extractions required, usually many, can be completed at one sitting The patient should be in the recumbent position and kept in bed for the rest of the day.

After-effects of nitrous oxide are usually conspicuous by their absence, but occasionally giddiness, nausea, faintness, and hysteria do occur, whilst very occasionally there are temporary disturbances of vision

Two cases which occurred in my own practice are interesting—in both cases nitrous oxide and air administered nasally was the anæsthetic, and in neither case was any difficulty experienced with the anæsthesia —

The first patient was a big, tall, healthy girl, aged sixteen years, who was to have the four first molar teeth extracted As the extractions on one side proved very difficult, taking ten minutes, the opposite side was left to be done a fortnight later Recovery after this first administration was uneventful When the patient attended the second time she said, "Please don't make me blind this time" It appeared that when she got out of doors after the previous anæsthetic her vision was very misty and this persisted for twelve hours The second anæsthetic was short, the other two molars being extracted in two and a half minutes This, however, was followed by misty vision for two hours The only thing that could be found out at all abnormal about this patient was that the mother stated that she was "difficult" over her feeding and would often only take an apple and a cup of coffee for her breakfast.

The second patient was a healthy girl, aged twenty one years, of average build A lower wisdom tooth was extracted under nitrous oxide and air administered nasally—time, two minutes On recovery patient vomited copiously, a friend present in the room said there was no need to worry about this as the patient often vomited if worried or upset When she ceased vomiting the patient complained she could not see, and I found I could bring my finger up to almost touching her eyes before she closed

them. The friend then volunteered the information that the patient's brother had had diplopia for two days after appendicectomy. This patient slowly recovered normal vision—it being two days before she could read.

PROLONGED EXTRACTIONS

For the second class of patient mentioned at the beginning of this article, the best method of anæsthesia is undoubtedly the endotracheal administration of nitrous oxide and oxygen by means of Magill's wide-bore rubber tubes passed by the nasal route, as these operations may last an hour or more. The most useful size of tube for an adult is No. 7 or No. 8. It is a great help if before the administration is begun the nose is lightly sprayed with 10 per cent. solution of cocaine. Premedication is necessary and the following are alternatives:—

For adults (1) Omnopon, ⅓ grain; atropine sulphate, 1/100 grain.

(2) Omnopon, ⅓ grain; scopolamine, 1/150 grain, an hour beforehand.

(3) Omnopon, ⅓ grain; scopolamine, 1/150 grain, an hour before, and evipan or pentothal intravenously in bed immediately before the administration.

(4) Avertin per rectum—dose according to body weight as shown on Bayer's surgical chart.

I prefer omnopon and atropine or omnopon and scopolamine, as although it is sometimes necessary to give ether in addition to the nitrous oxide and oxygen for the passage of the tube and sometimes necessary to add small amounts of ether at intervals during the operation, recovery and return of the cough reflex are much more rapid.

For children, suitable doses of omnopon and atropine or avertin per rectum, or paraldehyde, 60 minims per stone of body weight in olive oil per rectum beforehand, give satisfactory results.

As soon as the endotracheal tube has been passed, gauze, wrung first out of water and then out of liquid paraffin, should be packed into the throat alongside the tube so as to ensure that there shall be no breathing around the tube and to shut off the nasopharynx and also to prevent blood or fragments of bone being inhaled or swallowed Gauze treated like this for packing does not cause sore throats afterwards This is an intubation method with rebreathing and high pressure is not required Either one of the varieties of Boyle's apparatus fitted with Magill's rebreathing bag, corrugated wide-bore tubing and expiratory valve or a McKesson apparatus give satisfactory results Local or regional anæsthesia is a satisfactory alternative in certain of these cases

ALTERNATIVE METHODS OF ANÆSTHESIA

(*a*) If an endotracheal tube of suitable size cannot be passed through the nose, one can be passed orally and the throat and mouth packed and anæsthesia maintained in the same manner as when the tube has been passed by the nasal route

(*b*) If for any reason it is not desired to pass an endotracheal tube, two rubber tubes long enough to reach almost to the aperture of the larynx can be passed, one through each nostril, and connected by a special fitting to the Magill's valve Anæsthesia is maintained with nitrous oxide and oxygen, supplemented by ether if necessary, the mouth and throat being packed in a similar manner to that used with endotracheal methods

(*c*) Nasal nitrous oxide and oxygen after premedication This can be used for patients in whom it is desired to do a complete clearance at one sitting and in whom no great difficulty is anticipated with the extractions, or for patients with a history of bleeding in whom it is desired to extract a few teeth

at a time very deliberately and perhaps suture the gums afterwards. The mouth is packed as for an ordinary nasal administration.

It is not a suitable method for an operation of any length or difficulty and is certainly more wasteful of "gas" than the endotracheal method. It should be used with the patient recumbent and the head of the table raised.

CHAPTER X

LOCAL ANÆSTHESIA AND ANALGESIA

By W. H. C. ROMANIS, M.Chir., F.R.C.S.

CHAPTER X

LOCAL ANÆSTHESIA AND ANALGESIA

THE subject of local anæsthesia is one which for some years has given rise to a good deal of discussion and disagreement among British surgeons. Though every surgeon would admit that it is eminently suitable for many small and minor operations, there are others, in a minority, who advocate its use for almost every form of major operation. There is no doubt whatever that local anæsthesia is much more extensively used on the continent, especially in Germany, France, and Switzerland, than it is in this country, but many surgeons are of the opinion that such extensive use of it is never likely to be made in England. It must be remembered that in most continental centres, the standard of general anæsthesia is low, and the methods of administering respiratory anæsthetics, taken all round, are poor. Little effort appears to be made to train specialized anæsthetists and, however high the standard of surgery in a continental centre may be, it is unusual to find equally capable anæsthetists. Moreover, the continental patient is of a somewhat different type from the British one; he is inured to military discipline, and accustomed and instructed to put up with the discomforts, frights and alarm of major operations performed under local anæsthetics, in a way in which the average British patient would not. These discomforts under local anæsthesia, though admittedly slight, can be very

real, especially in a nervous patient, and they comprise such things as the pain of the needle pricks, a certain amount of pain and discomfort from pulling on and stretching the tissues, alarm at seeing the inside of the operating theatre and the surgeon in his mask and overall, and hearing the clatter of instruments and conversation of the surgeon and his assistants, while for some operations the patient has to lie motionless in a somewbat constrained and uncomfortable position for long periods. These few reasons probably account for the very much greater use that is made of local anæsthesia in Continental centres than in England.

English patients appear to be divided into two classes—the larger class who dislike the thought of having a major operation under local anæsthesia and of being in any way conscious during the proceeding, and the smaller class, who equally dislike the thought of giving up their consciousness, and possibly fear the discomforts of a general anæsthetic, negligible though they are by modern methods.

ADVANTAGES AND DISADVANTAGES OF LOCAL ANÆSTHESIA

The practical question of local anæsthesia should be considered under the two main headings of the use of local anæsthesia alone without any other anæsthetic, and its use as an adjunct to various measures of general anæsthesia. Local anæsthesia has in general certain definite advantages and disadvantages; thus it does away with any unpleasantness there may be attached to respiratory anæsthetics such as smell, taste, and sickness, and definitely diminishes the risk of chest complications afterwards, though it by no means completely excludes

their liability. It is said to diminish the shock of operative procedures by cutting off sensory impulses and preventing them from reaching the central nervous system, and naturally much reduces any tendency to post-anæsthetic vomiting, retching or coughing. When used as an adjunct to general anæsthesia there is no doubt that less general anæsthetic will be required and in the operations of abdominal surgery the requisite relaxation of the patient may by this means be obtained more easily. The disadvantages of local anæsthesia are that in the first place any operative procedure will be much prolonged by the preliminary injections, and perhaps also by frequent pauses during the operation for further injections Its advocates allege that this does not matter, and are prepared if necessary to spend many hours upon one operation: other surgeons, however, are of opinion that this prolongation of operative procedures, together with the attendant fright and alarm which may be associated with local anæsthesia cause an amount of shock which more than counterbalances the shock-diminishing effect of the local analgesia. Local injections of anæsthetic solution sometimes produce a little delay in the healing of wounds, and the tissues in and around the scar are liable to remain tough and indurated for some weeks afterwards. Such injections of a local anæsthetic solution must not of course be made in the presence or neighbourhood of acute or chronic septic infections.

In general it may be stated therefore, that the indications for the use of local anæsthesia are as follows:—

(a) In elderly and feeble patients, in whom it is felt that every possible precaution should be taken to diminish shock.

(*b*) In toxic patients, or those with deficient hepatic or renal function, in order to avoid any additional toxæmia produced

by the administration of such drugs as chloroform, ether, and avertin

(*c*) In certain special operative procedures to be described later, in which some surgeons feel that better results are obtained by employing local anæsthesia

In connexion with all these indications, however, it must be remembered that modern methods of general anæsthesia with the use of extensive premedication, and the employment of such products as gas and oxygen or cyclopropane, will probably achieve all the advantages that are claimed for local anæsthesia, with the exception of the prolonged six and eight hour operations which some surgeons practise It must also be remembered that when using local anæsthetics the greatest gentleness must be employed and that there must be no pulling of tissues Hæmorrhage at the time of the operation is often diminished by the adrenaline in the local anæsthetic solution, but this in its turn may lead to a greater tendency to reactionary hæmorrhage afterwards

Local anæsthesia is definitely contra indicated in children, in nervous patients, in those who have a definite dislike for its use, in the case of certain regions and organs of the body to be described below, and in the presence of septic or other infections

METHODS OF ADMINISTERING LOCAL ANÆSTHESIA

Two main methods of administering local anæsthesia are in use —(*a*) by means of nerve blocking, (*b*) by means of diffuse local infiltration

(*a*) *Nerve blocking* —This method of administering local anæsthesia consists in anæsthetizing all the sensory nerves supplying the area to be operated upon This may either be done quite close to the operation area itself, or more commonly

at a considerable distance away from it. It is achieved by injecting the local anæsthetic solution at a selected spot all round the sensory nerves supplying the area of operation. It is neither necessary nor wise to inject the solution into the nerves themselves, but a large amount of it should be deposited within quarter of an inch of each nerve trunk. After this procedure anæsthesia should come on in about quarter of an hour, and its duration will depend upon the nature of the solution used.

It must be remembered that a temporary paralysis of the muscles supplied by the nerves concerned will also be produced, and in fact this may be one of the advantages of the method; for in abdominal operations complete muscular relaxation of the muscles of the abdominal wall can be thus obtained On the other hand it must be remembered that this method is much more difficult to perform than the alternative method described below, as an exact knowledge of the anatomy of the nerves concerned and of their distribution is required; nor is the procedure suitable for operations on every part of the body, and it is particularly used in operations on the limbs, especially the arm, where infiltration around the main nerves in the upper arm will anæsthetize the forearm and hand. It is also practised extensively for abdominal operations, and here the lower six dorsal nerves should be anæsthetized. This may be done by infiltrating the tissues around the nerves either where they run in the intercostal grooves by inserting the needle in the lower six intercostal spaces in an upward direction, in the anterior axillary line, or else after the nerves emerge on to the abdominal wall, by infiltrating them through multiple punctures with a long needle where they lie between the muscles of the abdominal wall just below the costal margin in both sides. In this latter procedure the lowest puncture

must be placed far back in the loin in order to pick out the last dorsal nerve, and about 2 or 3 c cm of solution should be placed around each nerve To complete the anæsthesia it is wise to infiltrate the skin in the line of the proposed incision by the method of local infiltration described below By this method perfect abdominal relaxation can usually be obtained, though some degree of general anæsthesia will also be required

Thyroid operations, and other operations on the neck can be performed by this method though it is more usual here to use the method of local infiltration

Operation upon the skull and brain may be performed by a method which is really a combination of this method and the diffuse infiltration described below The skin in the lines of the proposed incisions in the scalp is infiltrated locally, and then an infiltration of anæsthetic fluid into the deeper layer of the scalp is made almost around the whole skull in the neighbourhood of its base to pick out the individual sensory nerves of supply, in the prolonged operations lasting seven or eight hours or more, which are the fashion at present among certain cranial surgeons, the anæsthesia naturally does not last the whole time, but has to be repeated

Nearly all the above proceedings will be rendered much easier and much more comfortable for the patient if they are accompanied by one or other form of general anæsthesia or premedication

Spinal anæsthesia, para sacral infiltration and splanchnic anæsthesia though really varieties of the above methods are usually regarded as a separate subject and will not be described in this article

(*b*) *Local infiltration*.—In this method the skin in the line of the proposed incision, and the subcutaneous tissues in the

operation area, are extensively infiltrated with the local anæsthetic solution. In most cases this is all the infiltration that need be done, as the muscles and most of the deeper tissues are more or less insensitive. In other cases, as the deeper parts are reached during a dissection, further infiltration of deeper layers will have to be undertaken. This method is the method *par excellence* for many minor operations. It is admirable for the removal of superficial swellings, such as warts, rodent ulcers, sebaceous cysts, lipomas and similar lesions. It is also employed largely for plastic operations upon the face and other soft tissues and in empyema operations. In this last type of operation, however, as in other operations in which bones are dealt with, it must be remembered that it is difficult or impossible to anæsthetize bone, though partial analgesia may be obtained by infiltrating the periosteum, and that in any case the wrenching or cracking movements, when a bone is cut, will be appreciated by the patient and cause considerable discomfort. At this stage of the operation therefore, it is both wise and humane to administer some form of short general anæsthesia. In general it should be remembered that local anæsthesia is by no means always as painless as the surgeon says it is, and that any roughness, pulling, or dragging of tissues and any manipulation of a bone is almost certainly felt as pain by the patient.

I have a clear recollection of two medical men who had had the first stages of thoracoplastic operations performed by well-known continental surgeons under local anæsthesia, which the surgeons stated was absolutely painless. So little, however, did the patients agree with this statement that when the second stages of the operation had to be done they both preferred to come back to England and have these finished under general anæsthesia.

ANÆSTHETIC SOLUTIONS TO BE EMPLOYED

Since cocaine was originally introduced as a local anæsthetic many modifications and new drugs of a similar kind have been

put upon the market, the aim and object of them all being to produce as good or better anæsthesia and at the same time to do away with the possibility of toxic symptoms. That cocaine is a toxic and dangerous drug there is no doubt. Many people show a marked idiosyncrasy towards it, and are affected by faintness, sickness, and collapse, when it is administered, while disasters have followed its use by injection into the tissues or by installation into the urethra for the passage of urethral instruments. It is therefore practically never used now except in the mouth, nose and throat where it is employed either by means of a spray or applied to the mucous membrane by pledgets of cotton-wool soaked in a dilute solution.

Stovaine, novocain, percaine and eucaine, are other similar drugs which are extensively employed, and which are far less toxic. Stovaine is probably the most toxic, and percaine the least. Stovaine is also seldom used now except for spinal anæsthesia, and novocain and percaine are the drugs which are by far the most extensively employed. There are many good proprietary drugs; panthesine is one which I have used considerably for minor procedures. Others in common use are novutox, which is self-sterilising, procaine, ethocaine, planocaine, and pantocain.

It is a common practice and a useful one to combine adrenaline with many of these local anæsthetic solutions. This, by producing a local vasoconstriction, prevents the anæsthetic solution from flowing too far away from the site of injection and thereby renders it more effective and of longer duration while the vasoconstriction produced by the adrenaline may actually assist in controlling hæmorrhage during the operation. It must be remembered, however, that when this effect passes off, the tendency to a reactionary hæmorrhage will be greater than if no adrenaline were used.

Novocain is generally used in a solution of half, one or two per cent., with which may be combined 5 minims of adrenaline to the ounce. Curiously enough, the strength of solution used does not seem to make much difference to the effectiveness of this anæsthetic.

A favourite local anæsthetic solution containing novocain is the following:—

Novocain	6 grains
Sod. chloride	15 grains
Adrenaline (1–1,000)	15 minims
Distilled water to	200 c.cm.

The whole of this may be employed if necessary. A few cases of apparently toxic effects following the installation of novocain have been reported, but I am doubtful if this is really so, for it is quite possible that any general effects of this kind may be due to the solution having been injected by mistake straight into a vein, and therefore being received by the patient in a concentrated form. I have used the above solution containing novocain in well over a thousand thyroid operations, in which the whole of the solution containing its 6 grains of novocain has been injected, without seeing any effects that could possibly be attributed to it.

Percaine is used in strengths considerably less than novocain, the usual percentage strength of such a solution being 1 in 1,000. The result is that large amounts may be used while its effect is undoubtedly much more lasting than in the case of novocain.

The various proprietary local anæsthetic solution preparations are usually supplied in ampoules or receptacles of the standard strength ready for use.

Recently use has been made of local anæsthetic solutions made up in an oily basis with a view to prolonging their anæsthetic action for several days or even weeks in order to over-

come the after-pain of operative procedures Such a solution is proctocaine which is usually used ready prepared in 5 c cm ampoules and is extensively employed for anal and rectal operations (often in conjunction with some other anæsthetic) to diminish the post-operative discomfort, for the first few days after the operation

APPARATUS TO BE USED

Though countless special syringes have been devised for introducing local anæsthetics, such as Barker's and Pick's, in most cases all that is really necessary is a good Record syringe of a size depending upon the amount of anæsthetic to be used The essential thing from the point of view of the patient's comfort is to use a small and sharp needle If a large amount of local anæsthetic is to be used it will take a long time to flow through a small needle, but this objection, however, may be overcome by the use of a fine needle to infiltrate a small area of the skin, through which area a larger needle may be inserted to infiltrate the deeper layers When a large amount of local anæsthetic is going to be used, and when its use may have to be continued during the operation, it will be an advantage and will save time to employ one of the various types of syringe which are on the market in which there is a two-way valve, and the anæsthetic solution is sucked up through a rubber tube from a receptacle In this way by alternately pressing the barrel of the syringe up and down, the fluid can be drawn into the syringe and injected into the tissues, without having to detach the syringe from the needle and insert it into a reservoir of the solution to refill it each time A syringe in which the nozzle instead of emerging from the centre of the end of the syringe, is attached to the rim of the end, is considered an advantage by some surgeons, and often syringes have a cranked or angled tube connecting them to the needle

METHODS OF EMPLOYING LOCAL ANÆSTHESIA IN VARIOUS ANATOMICAL REGIONS

It is impossible in a short article such as this to give a description of all the different ways in which local anæsthesia is employed, and no attempt will be made to give a description of its use in ophthalmic or oto-rhinolaryngological operations. Indications of its possibilities in various other standard operative procedures are as follows.

Abdominal operations.—An account has been given above (see p. 179) of the way in which the dorsal nerves may be anæsthetized in abdominal surgery. This, combined with a field block (infiltration of the line of the skin incision) will give sufficient anæsthesia and relaxation to open the abdominal cavity in about a quarter of an hour after injection. It must not be imagined, however, that this proceeding alone would be either pleasant or comfortable for the patient, and it is almost essential that he should also be given some modified form of general anæsthesia. Thus a large dose of morphine, hyoscine, or scopolamine, is often employed, which will produce semi-unconsciousness—or better still, one of the basal anæsthetics may be used, such as avertin or the more short-lasting evipan or pentothal. Even then if the relaxation is not sufficient, the procedure may be supplemented by a minimal amount of gas and oxygen. It is wise before opening the parietal peritoneum to infiltrate this structure also with the solution. Inside the abdomen further infiltration will have to be undertaken depending upon what type of operation is to be performed. It is in gastrectomies and other upper abdominal operations that the proceeding has its chief use, as by this means the liability to chest complications is greatly reduced. In a gastrectomy, therefore, after opening the abdomen it is necessary to infiltrate the lesser omentum, the greater

omentum and the nerve plexuses at the root of the cœliac axis artery By this method, a gastrectomy or similar operation can be performed with comfort both to the surgeon and patient, but it must be remembered that the proceeding will take much longer than if local anæsthesia were not employed

Minor operations on the skin and subcutaneous tissues—Local anæsthesia is excellent for the performance of such minor procedures as removal of warts, rodent ulcers nævi, sebaceous cysts, subcutaneous lipomas, small superficial foreign bodies, scars and other simple plastic procedures The comfort of the patient may possibly be increased by a small preliminary dose of morphine hyoscine, or other sedative but this is not really necessary in many cases, and is undesirable if the patient is going home straight away afterwards All that is necessary is for an infiltration of local anæsthetic to be made into the skin in the line of the proposed incision and an infiltration of the subcutaneous tissues sufficiently far around to embrace the operation area Similar methods can be employed for the extraction of teeth, though in this case rather than infiltrating the tooth socket involved it is better to block the dental nerves concerned by an injection of local anæsthetic into them at some distance above the tooth

Reduction of fractures—Most fractures can be painlessly reduced by means of local anæsthesia, but though the process may be painless and convenient for the patient, in the case of large bones and of muscular individuals it will be found that the muscular relaxation is not so good as when general anæsthesia is employed With a large syringe and needle a sufficient quantity of novocain solution 1 or 2 per cent, is injected between the broken ends of the bone into the hæmatoma surrounding them The amount required varies from 3 to 20 c cm according to the size and nature of the fracture, the

limb, and the patient. By this means a painless reduction of the fracture can be obtained.

Operations upon the thyroid gland and neck.—In severe cases of exophthalmic goitre local anæsthesia is almost a necessity, as by its means the operative mortality in all cases of Graves' disease, mild and very severe, has been reduced to less than 2 per cent. Although the method of nerve blocking can be used, in most instances that of direct local infiltration is employed. Whereas in severe cases local anæsthesia alone is essential, in the milder cases many surgeons employ it in conjunction with general anæsthesia, or do not use it at all.

The patient is usually given a large dose of some preliminary hypnotic, either morphine and hyoscine, avertine or, better still, paraldehyde by the rectum, 1 gramme per stone of body weight, with a maximum of 10 gm. After this has taken effect the local anæsthetic is injected. I always use the prescription given on p. 183. With a small hypodermic needle, an area the size of a sixpence in the skin, in the mid-line of the neck and in the line of the incision, is infiltrated. Through this area with a large needle the fluid is inserted into the subcutaneous tissues throughout the area of operation on both sides, reaching up to the angle of the jaw and the hyoid bone, and down to and behind the clavicles. The whole 200 c.cm. is injected and the pressure of this is sufficient to drive the solution down into the deeper tissue planes, so that no further injection will be required during the operation. The local anæsthetic with the adrenaline in it renders the tissues comparatively non-vascular and to a surgeon experienced in this method the operation is actually easier than when performed under general anæsthesia alone. In this, as in all other operations under local anæsthesia, it must be remembered that the greatest gentleness and delicacy must be employed.

Crushing or avulsion of the phrenic nerve is almost always performed under local anæsthesia, as the patients are usually tuberculous. The method employed is that described above, although the area of infiltration is considerably less. A certain amount of discomfort will be experienced while the phrenic nerve is being pulled upon. Small tuberculous glands in the neck and dermoid cysts can also easily be dealt with by this method.

Operations on the chest.—As has been stated above the performance of large operations upon the chest is practised abroad almost extensively under local anæsthesia, but is by no means free from pain to the patient unless he is definitely under the influence of some narcotic or general anæsthetic. For such major operations as lobectomy or thoracoplasty, a high spinal anæsthetic is therefore far more suitable. Some surgeons prefer to do operations for empyema by means of local anæsthesia alone, and there is no doubt that in patients who are seriously ill or toxic, this is a definite advantage. The line of the skin incision is infiltrated with local anæsthetic, as also are the deeper tissues, but though by infiltrating one or two of the intercostal nerves above and below the rib to be sectioned, a great deal of help can be given, it is difficult to prevent the patient feeling discomfort while the bone is actually being cut. During this stage of the operation, therefore, a little gas may be given with advantage.

Operations on the skull and brain.—Cranial operations are often performed by means of local anæsthesia, but here again it is almost essential to have the patient practically unconscious and deeply under the influence of some such drugs as morphine, hyoscine, avertin, scopolamine, or gas and oxygen. The line of the skin incision is infiltrated with local anæsthetic and the known cutaneous nerves are also picked out in the

neighbourhood of the base of the skull. In order to do this satisfactorily, it is often wise to place a ring of infiltration all round the skull from the region of the eyebrows, above the external meatus and back to the external occipital protuberance. No further structures are anæsthetized as the dura mater and cerebral tissues appear to be insensitive. It must be remembered that in prolonged operations in this neighbourhood, as is the practice of some surgeons, the effects of the local anæsthetic will wear off before the end of the operation. Further injections will have to be made.

Other regions.—Many other operations can be performed under local anæsthesia if deemed wise or necessary. Thus herniæ may be done by the method of local infiltration, as also may appendix operations and smaller procedures of this kind. On the other hand, in general, children and nervous subjects are not suitable patients for local anæsthesia, while certain parts of the body which are abnormally sensitive, such as the breast, kidney, bladder, palm of the hand or acutely inflamed tissues are also unsuitable, largely because of the pain caused by the insertion of needles to inject the local anæsthetic and the stretching of the tissues produced by the injection.

CHAPTER XI

POST-OPERATIVE CARE. ANÆSTHETIC ASPECTS

By L. W. MAGILL M.B., D.A.

CHAPTER XI

POST-OPERATIVE CARE: ANÆSTHETIC ASPECTS

IN considering the subject of post-operative complications it is difficult to dissociate the effects of anæsthesia from those of surgery. It is frankly admitted that in many cases these complications may be due to the anæsthetic or its mode of administration, but as anæsthesia is invariably accompanied by surgical interference of some kind it seems fair to divide the responsibility between the chief parties concerned. This contention is worthy of consideration since the more serious post-operative complications commonly occur after severe operations. Another aspect of this problem deserves mention here, namely post-operative pulmonary disease. As surgery developed, a closer examination of all the factors concerned in producing post-operative effects necessitated a modification of the view that, say, pneumonia following operation was exclusively the result of the anæsthetic; and it is now realized that trauma, post-operative pain, or a pre-existing state of upper respiratory tract infection or of lowered resistance, may also be responsible.

The treatment of post-operative complications is in the first instance preventive. Prevention entails careful judgment of the patient's condition, careful selection of a combination of agents, and of a method of administration suitable for the particular operation, skilful administration, and careful supervision on return to bed. To say that a patient "has taken an

anæsthetic badly" is as often as not an admission that one or other of these factors has been overlooked. A further condition demanded is a non-traumatic surgical technique. Tearing of the muscles, and forcible traction on viscera give rise to states for which anæsthesia is apt to be unjustly blamed.

It is well to realize that with the exception of anæsthetics which are strictly local in action, all the agents employed are depressant in their effects upon the human organism: some are actually destructive. When there is superimposed upon this depression the results of surgery, comprising wide exposure of tissues, trauma, shock and hæmorrhage, it is apparent that the assessment of the patient's ability to withstand this concerted assault is of supreme importance. The ideal aimed at should be delicate surgery and light anæsthesia, the excellent effects of which are borne out in practice by unexpectedly successful results in elderly or gravely ill patients

There exists in every individual what may be called a physiological balance In youth and in the healthy this balance is elastic within a certain range In old age and in the presence of disease, on the other hand, the degree of interference tolerated is greatly diminished. Nor must it be forgotten that, unlike the laboratory animal, the human subject is not a standardized product. Even in health environment, temperament, and habits of life are striking factors in the make-up of the individual The importance of estimating the patient's condition in this way is greater when non-volatile drugs are employed for, while easily administered, they are irrecoverable and incapable of control when once given.

Two other points require mention before a detailed consideration of post-operative after-care is made—basal anæsthetics and physical fitness. The agents employed as basal anæsthetics are not universally applicable as complete

anæsthetics in themselves and frequently require supplementary measures. Herein lies the danger. It may be easy enough to administer ether by itself, for the margin of safety is wide, but combination of this anæsthetic with basal agents is an undoubted handicap to an anæsthetist accustomed only to the administration of ether alone. The demand for basal anæsthetics is an ever increasing one, and their application is often left in the hands of the inexperienced. No one will deny that, administered in such circumstances, basal anæsthetics have called forth much hostile criticism.

Finally, it is obvious that every patient who comes to operation should be in as fit a state as possible. It is particularly important to bear this in mind when it is remembered that nowadays a number of women make a practice of dieting in order to keep slim. This often leads to under-nourishment and may, if the operative interference is serious and prolonged, be followed by dire consequences, owing to the patient's depleted reserves. A simple and nutritious diet should be insisted upon for a few days prior to operation, but this does not mean that alcohol or tobacco, if usually taken, should be forbidden.

Below an attempt is made to examine post-operative complications from the anæsthetic standpoint, and to show that given a co-operative surgical team these undesirable after-effects may be prevented in the first instance in some cases, though their avoidance in every instance is naturally beyond the anæsthetist's control. When such complications arise from the anæsthetic suggestions for treatment will be given.

OBSTRUCTION OF THE AIRWAY

When an operation is over it is the anæsthetist's responsibility

to ensure the safety of the patient before removal to bed, and to be certain, as far as possible, of the competence of the nurse in charge during the period of recovery of consciousness. It is at this time that alarming events are liable to occur, for which unskilful management (and not the anæsthetic) is to blame. The commonest occurrence is partial or complete obstruction of the airway due to dropping of the jaw or of the tongue, or to vomiting. In such an emergency an incompetent nurse may leave the patient in order to summon help and in the meantime cyanosis may have developed to an alarming degree. The simple procedure of supporting the jaw, which any nurse is capable of performing, is often all that is required to achieve a clear airway. It is to be regretted that many nurses are unable to differentiate between *efforts* at respiration and the actual occurrence of free ingress and egress of air in the patient's respiratory passages. Sometimes all the accessory muscles of respiration may be at work in the endeavour to effect the entry of air without result; at other times, with a completely unobstructed airway, the respiratory excursions may become shallow, though perfectly sufficient for the needs of the patient at this period. Thus the alarm may be given (1) because the patient is breathing but "black," or (2) because he is "not breathing," though his colour is good.

The anæsthetist must take every precaution as soon as the operation is over to keep the airway free. When there is no surgical contra-indication this can generally be accomplished by placing the patient as far as possible in the lateral position with a pillow behind the shoulders, or preferably in the semi-prone position. This prevents the tongue from falling backwards and facilitates the expulsion of vomitus. Should any tendency to respiratory obstruction still exist with the patient in this position, an artificial airway may be used; but tongue

forceps of any kind are better avoided. If, in the case of an emergency, the tongue has to be drawn forwards, a right-angled tongue depressor or the handle of a tablespoon causes no trauma and is equally effective.

When a wide-bore rubber endotracheal tube has been employed during the operation, it is frequently both convenient and safe to leave it in position until the cough reflex has returned; but it must be remembered that if vomiting occurs after the protection offered by positive endotracheal pressure, or a throat pack, or an inflatable tracheal cuff, has been withdrawn, there is a risk of vomited matter entering the wind-pipe during inspiration. This will be minimized by the patient being in the lateral or semi-prone position. When an intranasal tube is employed, the possibility of occlusion by clenched teeth is avoided.

RESPIRATORY DEPRESSION

Apart from the obstruction factor, and when the airway is quite free, the significance of shallow respiration may frequently be exaggerated. In deep sleep snoring (which is nothing less than partial respiratory obstruction) causes increased frequency and depth of breathing, whereas the breathing is quiet or even shallow when the airway is completely unobstructed. When general anæsthetics are administered without carbon dioxide absorption (or, in fact, when there is an accumulation of this gas from re-breathing) during the course of the operation, respiration is frequently stimulated. As a natural sequence withdrawal of this stimulation causes a certain degree of respiratory depression, which can be observed after so-called open ether given without any preliminary medication other than atropine. When, on the other hand, a basal anæsthetic such as avertin has been given beforehand,

its damping effect on respiration may be evident after the action of the supplementary agent has worn off and may last for some hours. If the dose of basal anæsthetic has been regulated with due care, however, every consideration having been taken of the state of the patient and the gravity of the operation, respiration in the immediate post-operative period should show no diminution in rate and amplitude beyond that which occurs in normal deep sleep If cyanosis occurs when the airway is patent, and no surgical cause is responsible, the dose of the basal anæsthetic has probably been *misjudged*.

Treatment in such cases aims at increasing the metabolic rate and detoxicating the basal agent. Carbon dioxide and oxygen should be given at intervals, together with coramine, icoral, or lobeline. Coramine appears to be as efficient as any of the remedies which can be injected. When the gravity of the symptoms demands an immediate effect the drug should be given intravenously in doses of from 1 to 4 c cm.

Opium derivatives in any form are contra-indicated in the presence of respiratory depression. After avertin, it is in any case a good practice to avoid them until consciousness has fully returned. This precaution is worthy of particular stress. The well-meaning practitioner, who is anxious that his patient should know neither pain nor discomfort (abetted by the night nurse who is anxious to be undisturbed), contributes nothing to the patient's welfare by giving an opiate before avertin is fully detoxicated.

CIRCULATORY DEPRESSION

Apart from a state of acute shock or collapse, which is mentioned below, a mild degree of circulatory depression is not uncommon when a patient is put back to bed, but the degree of depression is consistent with the accompanying degree of

slight respiratory depression which follows withdrawal of the stimulation provided by the supplementary anæsthetic. It is no cause for alarm, and corresponds, in fact, to the conditions obtaining in deep sleep. It must not be forgotten that the progressive elimination of the anæsthetic, which is taking place at this period, also contributes to the occurrence of some circulatory depression by allowing pain stimuli to "get through" to the brain.

Treatment is indicated only in the aged and debilitated in order to prevent stasis in the pulmonary circulation, i.e. carbon-dioxide-oxygen administration, coramine, ephedrine, and saline per rectum.

SHOCK AND COLLAPSE

As a general rule shock and collapse are attributable to anæsthesia when the depth of narcosis is insufficient for the surgical procedure. From this it must not be deduced that the deepest general anæsthesia prevents shock, since afferent stimuli are still received. Light anæsthesia is frequently confused with a condition in which the patient is merely lightly unconscious and immobile, but not actually anæsthetized. In the latter circumstances shock is rightly attributable to the anæsthetist. Operations of any magnitude should be performed under light anæsthesia only when the reception of afferent impulses is prevented by nerve block, as pointed out by Crile.

The *treatment* of shock is a matter of cardiac and respiratory stimulants, raising the foot of the bed, and applying warmth, and fluids. If the oral route is barred, saline is better given per rectum (by the drip method) than intravenously. When neither rectal nor oral routes can be made use of, and the shock is severe, blood tranfusion may be required. As this comes within the province of the surgeon I make no more than a passing reference to it, nor to W. Wallther's (1936) interesting

practice of using plasma transfusion, which he regards as the ideal in this indication. One important point is frequently forgotten when fluid therapy is being considered—namely that if fluid is given by the alimentary route (oral or rectal) the body is better able to regulate its rate of absorption and to reject the excess if necessary.

POST-OPERATIVE DISTENSION AND URINARY RETENTION

Without going into etiological details it will suffice to say that the vicious circle of post-operative distension occurs when the patient has fully recovered from the anæsthetic. It is therefore illogical to lay the blame on an agent or agents already eliminated. In the treatment of the condition, suction by duodenal tube should be instituted when simpler remedies, such as turpentine enemas, and the use of flatus tubes, eserine, and pituitrin have failed.

C. H. Pratt (1936) gives a good account of its use during operation A duodenal tube is passed into the stomach and remains *in situ* during the operative interference, suction being provided by syphonage. This makes the surgeon's work considerably easier during upper abdominal operations, and, left in place after the operation, and subjected to aspiration at indicated intervals, secures the prevention of secondary distension.

Retention of urine is comparable in its mechanism to the state of affairs present in abdominal distension when there is inability to relax the anal sphincter. It is significant that retention follows operations such as herniotomy—irrespective of the type of anæsthesia—more frequently than those performed elsewhere. Abdominal distension, similarly, occurs to a lesser extent when the site of operations is not the abdomen.

VOMITING

A certain amount of nausea and vomiting is not uncommon

during the period of recovery from unconsciousness. So far as the anæsthetic is concerned this vomiting is generally of a transient nature, and by the use of "basal agents," supplemented by some non-toxic substance such as nitrous oxide and oxygen it is generally absent. Swallowed blood, ejected by the stomach as a foreign body can, of course, hardly be considered as an "anæsthetic aspect" of post-operative after-care.

The anæsthetist's concern is with the vomiting which may be classed as either (*a*) nervous, or (for lack of a better term) (*b*) true anæsthetic vomiting. Many patients—and an accurate parallel may be made here with some cross-channel passengers—make up their minds that they are going to be sick. For these, the nervous class, little or nothing can be done; retching may even commence before preliminary medication has been given, a previous experience of anæsthesia often contributing to its appearance. Midway between this nervous type of vomiting and the more serious "true" vomiting comes that due to sedative drugs such as morphine,and is explainable on the basis of idiosyncrasy.

True anæsthetic vomiting is a different matter altogether, being part of a vicious circle characterized by a gross upset of acid-base equilibrium. The patient, unable to retain fluid by mouth, is in a condition of dehydration resulting in acidosis and calling for energetic treatment. Most vomiting which persists for longer than eight hours may be classed in this category.

A detailed consideration of "acidosis" is out of place here, and it will suffice to say that following all inhalation anæsthetics (and even local ones) a diminution in the alkali reserve, accompanied by an increase in the urinary acidity and ketonuria, occurs. Patients in whom this state of acidosis exists

before operation—as in the old days of pre-operative starvation—become worse afterwards and its occurrence cannot in all cases be prevented by prophylactic administration of sodium bicarbonate, glucose and insulin. A significant fact is that R. Smith (1934) found that the incidence of post-operative vomiting was reduced to one-half by giving glucose 2 ounces *plus* insulin 5 units before operation and glucose 4 ounces (per rectum) and insulin 5 units afterwards.

An important factor in preventing post-operative vomiting is the use of a well-balanced anæsthetic prescription. In the first place it must not impose too heavy a burden on the organism as a whole and, secondly, it must be chosen with a view to the peculiarities of any given case The surgeon's demand for a routine anæsthetic—"I always have avertin for *all* my cases"—cannot be too strongly deprecated. "Well-balanced anæsthesia" comprises a suitable dose of a selected basal narcotic followed by nitrous oxide and oxygen—avoidance of ether and cholorform if possible, and otherwise the use of only a minimum quantity of these supplementary anæsthetics. Cyclopropane, which, according to Wesley Bourne, is the only anæsthetic not impairing the liver's function, bids fair to replace choloroform and ether entirely in this respect.

When vomiting occurs in a severe form the treatment is as for shock—fluid therapy, together with glucose-insulin as described above. A number of other remedies may be employed in the less serious case Drinks need not be forbidden: sodium bicarbonate and water, or tea with lemon. Ice, however, should not be allowed. Barbiturates may be used—chloretone and nembutal suppositories—and a few drops of adrenaline in water flavoured with peppermint is often successful.

PULMONARY COMPLICATIONS

Of all the anæsthetics which have been blamed for pulmonary

complications ether has been given the greatest prominence, despite the fact that they are equally common after spinal anæsthesia. The reason for this lies in the extensive use of ether the world over since it became established as a relatively safe anæsthetic. It is probable also that the impunity with which deep anæsthesia can be induced for the immediate needs of surgery has led to much indiscriminate, and frequently needless saturation of the patient. The "deepest possible" anæsthesia obtainable with ether still remains the ideal of many surgeons. It has been shown that the nature and duration of the operation have as great a bearing on the incidence of post-operative pulmonary complications as the anæsthetic used Thus the incidence of pulmonary complications is relatively high in upper abdominal and relatively low in pelvic operations.

The depth of anæsthesia required in the case of an upper abdominal operation subjects the pulmonary bases to a period of inactivity from which only the robust patient can escape unharmed. When this inactivity is prolonged, as it is during recovery from deep ether, the risks are further increased. When consciousness has returned active respiration is impeded by pain which necessitates the use of opiates—themselves respiratory depressants. These factors combine to bring about conditions favourable to pulmonary complications.

How can the anæsthetist contribute towards the prevention of these complications?

(1) By balancing the anæsthetic prescription (see section on vomiting, p. 201) in accordance with the type of patient and the nature of the operation. In old people and bad risks pre-anæsthetic medication when both long in duration and depressant in effect, must be avoided. A barbiturate which is rapid in action and detoxication is preferable, in small doses,

to avertin. The supplementary anæsthetic should be nitrous oxide and oxygen, but only as far as this combination is capable of satisfying surgical requirements without producing cyanosis. If muscular relaxation is required, as in high abdominal operations, a field-block of the abdominal wall can be carried out: failing this, cyclopropane may be substituted for nitrous oxide. "High spinals" should be avoided in old people, but if spinal anæsthesia is especially indicated let it be limited to a low block.

(2) By maintaining throughout the operation free respiration of normal amplitude and rate, and by preventing the entry of blood or vomited matter into the trachea

(3) By avoiding undue exposure of the patient in the theatre—especially exposure of extensive raw areas, as in amputation of the breast.

(4) By securing (as already indicated) a free airway at the end of the operation.

(5) By maintaining the rate and amplitude of respiration after the operation by means of carbon dioxide mixed with oxygen and coramine. Administration of these should be repeated, at intervals if necessary, until the patient is fully conscious. If there is no surgical contra-indication, a change should be made from the supine position The patient may be moved from one side to the other at intervals without causing undue disturbance. Opium should be withheld until the necessity for it is absolute, and even then the dose should be small. It is easy, and safer, to repeat a small dose as the need arises.

MINOR COMPLICATIONS

The post-operative complications dealt with in this section comprise a heterogeneous collection which, though of relatively small importance, commonly require attention.

Sore throats and pharyngitis.—Endotracheal anæsthesia occasionally gives rise to a sore throat which must now be recognized as a special sequel of this form of anæsthesia. Considering the increasing use of the method, the incidence of this complication is comparatively small. The sore throat is usually of short duration and of insignificant severity, though at times a patient may complain of it for several days. Rarely it is accompanied by aphonia which may persist for a week. Trauma is the cause, and is therefore avoidable. The more experienced the anæsthetist becomes in intubation technique the smaller is the incidence of this complication. The complaint may be localized *in the larynx*, in which case hoarseness is a feature. Occasionally it is sublaryngeal and accompanied by mild tracheitis with some cough and sputum. The latter occurs most frequently following operations for goitre which involves manipulation of the trachea. It is obvious that attempts to pass the tube when the glottis is closed will excoriate the mucous membrane, though it is significant that when the tube has been introduced into the trachea with precautions against trauma and has been well lubricated with vaseline, sore throat rarely follows operations performed in regions of the body other than the head and neck. The mucous membrane, which may be unduly desiccated from atropine injection or from other causes, should be swabbed with sterile paraffin as a routine measure.

Pharyngitis and ulceration of the soft palate and fauces result from excoriation by the speculum or from forcible introduction of dry gauze packing. Painful swallowing is the chief symptom. When the trouble is located in the larynx or trachea, inhalation of friar's balsam from an old-fashioned steam inhaler is a useful remedy. Painful swallowing and ulceration of mucous membrane respond well to a gargle of

potassium chlorate, carbolic acid and glycerin. Aspirin tablets are also useful as a local remedy.

Conjunctivitis.—This results from irritation from ether, from drying up of secretions from atropine, and from trauma by the anæsthetic mask It should always be avoidable. Cases of exophthalmic goire require special care.

Post-operative backache—This follows the stretching of the lumbar and sacral ligaments and causes much tribulation. The lumbar convexity should be suitably supported when the patient is on the operating table

Restlessness has been widely attributed to basal anæsthetics It is well to remember, however, that it is not uncommon after ether anæsthesia when no basal drug has been used. Post-operative restlessness of a violent nature is more common in children than in adults. It follows barbiturates such as nembutal more frequently than avertin. In adults troublesome restlessness is nowadays unusual after barbiturates, owing to the rapid detoxication of agents, such as pentothal and evipan Children who can be persuaded to swallow may be given chloral hydrate with good effect (1 grain in syrup for each year of age.) If swallowing is impossible the only alternative is a hypodermic injection of morphine. Extreme restlessness indicates a high metabolic rate, so that a suitable dose of morphine is not contra-indicated in such circumstances.

SPINAL ANÆSTHESIA

When a spinal anæsthetic is given there is a danger of a fall of blood pressure. A danger of respiratory failure results from a combination of this factor with paralysis of the accessory muscles of respiration. Some of the anæsthetic substance is, of course, absorbed into the blood stream.

Preventive measures against the complications following

"spinals" consist of the injection of ephedrine (some anæsthetists give this (1 grain) as a routine fifteen minutes before all administrations), the use of carbon dioxide when necessary and the adoption of the Trendelenburg position. Headache is now much less common than in the early days of "spinals" owing to the use of fine needles, which prevent leakage of cerebrospinal fluid. Should it occur, ephedrine is administered, together with abundant fluids per rectum or by mouth, and the usual remedies for headache, such as aspirin. A throbbing type of headache due to *increased* intracranial pressure may follow a "difficult puncture." This generally yields to a mag. sulph. enema (3 ounces in 6 ounces of water) and seldom requires intravenous saline. It must always be remembered that a fatal collapse may occur after the operation if any sudden change in position is made. Thus, if the Trendelenburg position has been adopted this must be maintained during the patient's transit back to bed and for three or four hours afterwards.

The need for protecting the patient from hot-water bottle burns is, of course, obvious.

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CHAPTER XII

RISKS OF EXPLOSION IN ANÆSTHESIA

By J. K. HASLER, M.B., B.S., D.A.

CHAPTER XII

RISKS OF EXPLOSION IN ANÆSTHESIA

THERE is a proverb to the effect that familiarity breeds contempt. The administration of anæsthetics is now such a familiar occupation to many medical practitioners that even if they do not feel contempt yet they are likely to become forgetful of the chemical properties of the anæsthetic agents used. It is as well to remember occasionally that nearly all the inhalational anæsthetics are easily combustible in the presence of oxygen. Since a continuous supply of oxygen is necessary to maintain life it follows that the majority of gaseous mixtures inhaled during anæsthesia are liable to explode under suitable conditions. The only anæsthetics which can be considered safe in this respect are nitrous oxide, when given with air or oxygen, and chloroform. Chloroform itself is not combustible but will permit combustion. A piece of cotton-wool soaked in chloroform will still burn and a smoky flame is produced owing to the decomposition of the chloroform. Of the other anæsthetics both ethyl chloride and divinyl ether are inflammable. Liquid ether is inflammable and when ether vapour is mixed with air, oxygen, or nitrous oxide it may become violently explosive. Lastly, explosive mixtures are produced with oxygen and any of the three hydrocarbon gases commonly used for anæsthesia, namely ethylene, acetylene, and cyclopropane.

EXPLOSIVE ANÆSTHETICS

Ethyl chloride will form an explosive mixture with air when the

amount of ethyl chloride in the mixture lies between 5 per cent. and 20 per cent. As it is not generally used for continuous anæsthesia but merely to induce anæsthesia before such short operations as the extraction of teeth or the removal of tonsils by the guillotine, the risk of a conflagration would appear to be small. Tubes of ethyl chloride, however, have the habit of rolling off the table or anæsthetic trolley if they are not put down carefully. If a tube of ethyl chloride falls on to the floor and breaks in the vicinity of a fire the liquid will instantaneously catch alight and the floor around the fire will be covered by a sheet of flame over an area of several square feet. In about one second the flame will have burnt itself out and the room will become filled with choky fumes consisting largely of hydrochloric acid which has been formed by the decomposition of the ethyl chloride. *Diuinyl ether*, which is also as volatile and inflammable as ethyl chloride, behaves in much the same way except that the resultant fumes of hydrochloric acid are not produced.

In the case of *ether* it has been found by experiment that mixtures of ether and air will explode when the proportion of ether in the mixture lies between 2 per cent. and 8 per cent. If, however, ether vapour is mixed with nitrous oxide instead of air an explosion will occur when the amount of ether lies between 1·5 per cent. and 16 per cent. The lower limit for explosion with ether and oxygen is also about 1·5 per cent. and the upper limit is probably higher than that for nitrous oxide. It may therefore be assumed that for risks of explosion nitrous oxide is nearly as dangerous as pure oxygen when mixed with ether, a fact not generally known The foregoing figures are taken from a report following experimental investigation of the subject by the London County Council. It should be noted, however, that the U.S. Bureau of Mines have also

carried out a similar investigation. From their experiments they found that a mixture of ether and air will explode when the percentage of ether lies between 1·85 and 36·5 and, when ether is mixed with oxygen the range of combustion lies between 2·10 per cent and 82·00 per cent. To put these facts in a more practical way it may be stated that the vapour produced when air, oxygen, or nitrous oxide is blown through the ether bottle of a Shipway apparatus or any gas and oxygen machine is extremely liable to explode in the presence of a spark. Even if the gases are also passed through the chloroform bottle an explosion may still occur. The flame produced will usually travel along the tubing of the apparatus and blow up the ether bottle. If oxygen is being given, either alone or with nitrous oxide or any of the hydrocarbon gases, the flame may travel down the patient's trachea with fatal results. Open ether on the other hand is relatively safe. Samples of air have been taken at a distance of two inches from the mask after an operation has been in progress for an hour and ten ounces of ether have been used. It was found that the percentage of ether vapour in the samples was too small to ignite. Any explosion in the presence of ether and air is less likely to damage the patient as there is not sufficient oxygen in the trachea to allow conduction of the flame. When the speed with which a glowing splinter of wood bursts into flame on being plunged into a test-tube of oxygen is considered, it is easy to see how pure oxygen can be much more dangerous than air if an explosion should occur.

With regard to the hydrocarbon gases both *ethylene* and *acetylene* have exploded when mixed with oxygen for anæsthetic purposes. The flame usually spreads down the trachea with fatal results. No explosion appears to have occurred yet with *cyclopropane* though the risks are as great as with the other

two gases. The reason for this is that cyclopropane has only been used for about four or five years and during that time the causes of explosions have been better understood and precautions have been taken to prevent them.

THE CAUSES OF EXPLOSIONS

The inflammable mixtures of oxygen and anæsthetic vapour which the patients inhale is perfectly safe under normal conditions. It is only when a sufficient degree of heat is present that combustion occurs. The source of heat is usually hot metal, as for example a cautery, or an electric spark which may arise either from an electric current as in a diathermy machine or from static electricity. Open fires in the operating room are usually quite safe unless some untoward accident occurs such as the dropping of an anæsthetic bottle on to the floor. Both the electric cautery and the thermo-cautery must be considered sources of danger as the essential part of these instruments has to be at red heat in order to fulfil its function. Metal need not, however, be hot enough to glow in order to cause an explosion. A case has been reported in which an explosion was caused by a dental needle which though hot was definitely below the temperature required for red heat.

Now that electrical apparatus plays an important part in modern surgery it is not surprising that it has been the cause of numerous explosions. The diathermy machine is the most obvious source of danger, particularly when used anywhere near the respiratory tract. Less obvious sources are such throat instruments as bronchoscopes and œsophagoscopes. These have to carry a current which illuminates the tiny electric light bulbs at their extremities. If the insulation is faulty in some way sparking may occur when the instrument is inside the patient and at least two explosions appear to have been

caused by this means. Another piece of apparatus which has caused an explosion is the electric motor which works a suction pump. While sucking blood and mucus from a patient's throat, as for example during tonsillectomy, a certain amount of anæsthetic vapour is also drawn away. Now if the motor is housed in a wooden box it is possible for the ether vapour drawn off to accumulate in the box until combustion point is reached, when sparking from the motor will explode it. This occurred at a London hospital a few years ago Another potential source of danger is X-ray apparatus as it is sometimes necessary to give an anæsthetic in the X-ray room. The risk would, however, appear to be small as any sparking which takes place is usually at some distance from the patient and at a higher level.

Finally, the risks due to static or frictional electricity must be considered. Most individuals are familiar with the crackling that is sometimes produced when a vulcanite comb is drawn through the hair. If this is done in a dark room it is possible to see the sparks that are produced by this manœuvre, and if the comb is subsequently drawn along the tips of the fingers sparks can be seen coming from the teeth of the comb These sparks may be dangerous in the presence of inflammable material. A fatal case occurred in 1897 when a woman's head caught fire while she was having a dry shampoo with some sort of lotion containing petroleum. On the anæsthetic trolley the passage of dry gases through rubber tubing may induce a charge of electricity that is not easily dispersed as most trolleys have rubber tyres to their wheels and are therefore insulated. The anæsthetic trolley may therefore be in a state of raised electrical potential and will earth its charge as soon as opportunity occurs which may be through the body of the patient or the anæsthetist. Many of the trolleys which run

between the operating theatre and the ward are now covered with pads of spongy rubber for the comfort of the patient. Friction caused by the passage of a dry cloth such as a blanket over the surface of this rubber will induce a charge in it and anyone who then places a hand on the rubber will experience a sharp shock as the charge is earthed through his body. These phenomena are most readily observed when the atmosphere is cold and dry. Such conditions prevail over extensive tracts of land such as the U.S.A. and central Europe and particularly during the winter months. In both the U.S.A. and in Germany explosions have occurred from sparks of static electricity and the problem of their prevention has been investigated. In the British Isles the risk is much reduced. This country enjoys an insular climate and the relatively high humidity of the air prevents the accumulation of static charges. During cold frosty weather, however, they may occur and it is interesting to note that Gilbert White, when describing a severe frost at Selborne in 1784, says: "I must not omit to tell you that, during these two Siberian days, my parlour cat was so electric, that had a person stroked her and been properly insulated, the shock might have been given to a whole circle of people." Recently there has been a tendency to reduce the humidity of the air in the operating theatres by the process of air conditioning. It is not without danger as in one of our newest hospitals an explosion has occurred which appears to have been caused by a static spark in an air-conditioned theatre.

It is perhaps convenient to consider, at this point, certain risks attendant on the use of oxygen cylinders. Oxygen as supplied to the public is under high pressure and when the valve of an oxygen cylinder is opened the gas rushes out through the narrowed outlet in the neck of the cylinder.

Heat may be produced by the friction of the escaping gas and any inflammable material in or near the valve is liable to ignite. Such substances as oils or grease or even particles of dust may catch fire in this way. Although they may be relatively non-inflammable in the presence of air they will burn freely in the presence of oxygen. It is for this reason that warnings are issued to keep the cylinders free from oil or grease and to keep the valves clean and free from dust. If a reducing valve is fitted to an oxygen cylinder the outlet for the gas is still further reduced. Many of these valves contain rubber in their composition and rubber is another substance that will burn freely in the presence of oxygen. As a precautionary measure any oxygen cylinder fitted with a reducing valve should be opened gently and the outlet from the reducing valve should be opened before the oxygen is released These dangers are present only with oxygen cylinders and not with cylinders of nitrous oxide or carbon dioxide. Reducing valves which are intended for use on cylinders of nitrous oxide may contain some bees-wax within them. It is therefore dangerous to use a reducing valve intended for nitrous oxide on a cylinder which contains oxygen. Apart from the risk of fire, damage may be done to the valve as the pressure for which it is constructed is less on a cylinder of nitrous oxide than on a cylinder of oxygen.

MEANS OF PREVENTION

The administration of anæsthetics in rooms which contain an open fire is a reasonably safe procedure provided that care is taken to prevent the upsetting of bottles containing ether or ethyl chloride. Portable electric fires should be kept at a distance from the operating table and away from the head end. Whenever the cautery or diathermy machine is used special

care must be taken. The use of basal narcotics, such as avertin or evipan, should be considered, and these may be supplemented by nitrous oxide and oxygen. Ether must not be used if the operation is in the neighbourhood of the respiratory tract. If a cautery is used in or near the mouth it may be desired to give the patient chloroform or nitrous oxide and oxygen. In such cases the ether bottle should be disconnected and removed from the apparatus. It is not sufficient to empty the bottle or turn off the ether. At least one case has occurred in which the ether bottle of a Shipway's apparatus was emptied but left connected to the apparatus. Ether vapour which still remained in the bottle was sucked over with the chloroform and caused an explosion. The possibility of explosions from electric-light bulbs on throat instruments must be kept in mind. If ether is being given when these are used it is better to drive it over to the patient by means of air from a hand bellows rather than by oxygen from a cylinder. If an electric-suction pump is used care must be taken that the vapour drawn off by the machine is conveyed away from the motor, particularly if this is housed in a box. The prevention of explosions from static sparks presents more of a problem as it is not easy to tell in advance where these will arise. It is now becoming common to earth theatre and anæsthetic trolleys by means of chains which trail along the floor for a few inches when suspended from the bottom of the trolley. In this way any charges which might accumulate are dispersed. In Germany it has also been considered necessary to earth the patient by means of a chain from the wrist to the operating table. In the U.S.A. attention has also been given to the floors of the theatres. When these are made of non-conducting material such as rubber, it has been suggested that strips of metal should be laid criss-cross into the floor so

to provide effective earthing of the theatre. Other schemes which are receiving attention are the placing of a wire spiral inside the rubber tubing of gas and oxygen machines or of incorporating some metallic element into rubber which will render it a conductor of electrical charges. It has also been suggested that use might be made of wire gauze such as is used in miners' safety lamps. A diaphragm of this placed inside the tubing of a gas and oxygen machine might prevent spreading of the flame should an explosion occur. These precautions may seem unnecessary in the humid climate of this country, but they are important to foreign anæsthetists who have found static sparks a real danger. It must also be remembered that there is a growing tendency to use dry flow-meters for regulating the proportion of gases in gas and oxygen machines instead of the old water sight-feed bottle which provided a certain amount of water vapour for the inside of the machine. This may constitute a danger for the future, especially if air-conditioning of theatres should increase. In some trades, such as dry cleaning, it has been found necessary to keep the humidity of the air above a certain level because of explosions that occurred owing to static sparks. The National Physical Laboratory have recently investigated the subject on behalf of the anæsthetic committees of the Medical Research Council and the Royal Society of Medicine. They commented on the fact that both the institutions which have adopted air conditioning of their theatres have been troubled with static sparks and they issued a note of warning against the excessive reduction of the insulating powers of rubber. If rubber tubing was made too great a conductor of electricity it might catch fire if it accidentally came in contact with a powerful electric current.

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